Metals as Resources

Contents: Data analysis exercises on the prices, abundance and reserve lifetimes of metals, and problems associated with their depletion.

Time: 2 periods or more, depending on number of parts attempted.

Intended use: GCSE Chemistry and Integrated Science. Links with work on reactivity, abundance, extraction and uses of metals.

Aims:

- To complement and revise prior work on metals and the reactivity series, and the extraction and uses of metals
- To show some of the factors affecting the price of metals
- To develop awareness of the finite nature of metal resources, and the desirability of encouraging replacement and recycling
- To provide opportunities to practise data analysis skills.

Requirements: Students' worksheets No. 604. If possible a copy or copies of newspapers giving current metal prices (for example *Financial Times, The Times*)

The unit is best used after some coverage of metal occurrence, extraction and the reactivity series. The class could usefully be divided into small groups to discuss the questions. Teachers may well wish to invent questions of their own based on the data. If possible, students should have an opportunity to check the metal prices in the unit against those in the financial pages of a current newspaper. This adds interest and immediacy to the exercise, and differences may lead to fruitful discussion.

The unit is in three parts, each fairly self-contained. It is not necessary to use all three parts, though they do complement one another.

Part 1 Production and prices
Part 2 Reserves and resources
Part 3 What happens when supplies run out?

Notes on some of the questions

Q.1 The first six metals in order of production quantity are: Fe, Al, Cu, Mn, Zn, Cr.

Q.2 The lowest production is for gold, mainly, of course, because of its rarity.

Q.5 The least abundant metals are generally the most expensive. The converse is not necessarily true, because for highly abundant metals like iron and aluminium, extraction cost becomes important.

Q.7

(a) Gold is more expensive than silver because of its lower abundance.

(b) Aluminium is more expensive than iron because of its higher reactivity and consequently greater extraction cost. The fact that aluminium has to be extracted electrolytically, and the fact that it forms 3+ ions, make extraction costs high.

(c) Copper is more expensive than aluminium because of its lower abundance.

Q.8 It is important to stress that metal prices are very sensitive and are determined by many factors in addition to abundance and reactivity. These include:

(a) Supply and demand. This is a most important and powerful factor, as can be seen by the fluctuations of metal prices from day to day.

(b) Political factors. The prices of strategic metals, particularly gold, are sensitive to world events. For example, the price of gold may rise at times of political tension, because of gold's importance as a backing for currency.

(c) Cost of processing ore (likely to be related to abundance). Country of production (labour costs, transport costs, etc.).

Q.10 There is an opportunity here to explore the whole question of the exploitation of developing countries' resources by industrialized developed countries, both at present and in the colonial past. Some developing countries' economies are heavily dependent on the export of minerals (for example, Jamaica with bauxite; Zambia and Zaire with copper) and this makes these countries vulnerable to price movements originating in industrialized countries. A further dimension is added by the position of South Africa as a major producer of many strategic minerals. The table below gives the major producing countries for some important metals.

Metal	*Major producers of ore*
Aluminium	Many countries including Jamaica, Guinea and Ghana
Chromium	South Africa, USSR
Cobalt	Zaire, Zambia
Copper	USA, Canada, USSR, Chile, Zaire, Zambia
Gold	USSR, South Africa
Iron	USSR, Australia, Scandinavia
Manganese	USSR, South Africa
Vanadium	South Africa, USSR

Q.12 Figures for reserves are constantly changing. One reason for this is the discovery of new reserves as old ones are used up. Reserves are also dependent on price: an increase in price of a metal may make it worth mining low-grade ores that were formerly uneconomic, and may hence increase reserves. The table below illustrates how the reserves of four metals have increased since the 1940s.

World reserves of four metals/million tonnes

Years	*Cu*	*Pb*	*Zn*	*Al*
1940s	91	31 to 45	54 to 70	1605
1950s	124	45 to 54	77 to 86	3224
1960s	280	86	104	11 600
1970s	543	157	240	22 700

However, it is important not to give a falsely optimistic impression; reserves really *will* run out one day, and students should be aware of the need for responsible use of mineral resources.

Qs 13 and 14 The problem of recycling is largely an economic one, and for a low-value metal such as iron the problems of collection and separation, and the particular difficulty of recycling alloys, may make recycling uneconomic. However, students should appreciate that there are other factors to consider beyond the economic ones, for example, the environmental desirability of recycling.

Q.15 'Tonnage' uses of metals may decrease in the future, with, for example, more use of concrete instead of steel. However, falling demand for tonnage metals in developed countries is likely to be offset by increased demand in developing countries. It will be difficult to replace specialist metals in such applications as conductors and high-performance alloys for machine-tools, aircraft, etc.

Further resource materials

The SATIS unit No. 310, *Recycling Aluminium,* takes further the whole question of recycling.

The Keep Britain Tidy Group Schools Research Project includes a useful unit, *Metals.* From: The Keep Britain Tidy Group, Bostel House, 37 West Street, Brighton, Sussex BN1 2RE.

Acknowledgements Figure 1 supplied by British Rail; Figure 2 supplied by Johnson Matthey Chemicals Ltd; Figure 3 supplied by COMPIX/ Commonwealth Institute; Figure 6 is reproduced by permission of the Department of Trade and Industry.

METALS AS RESOURCES

Metals have been used for thousands of years. More than sixty different metals are now extracted from the Earth and used by us. Each metal has its own properties which can be put to good use. These include strength, hardness, conduction of electricity, conduction of heat and individual chemical reactions.

As well as the pure metals, thousands of different mixtures of metals, called alloys, can be made. The alloys have their own properties, different from those of the original metals. This greatly extends the possible uses of metals.

Modern society depends heavily on metals. But how much of these vital resources do we have, and how long will they last?

This unit is in three parts:

Part 1 Production and prices
Part 2 Reserves and resources
Part 3 What happens when supplies run out?

Figure 1 Metal rails, metal wheels, metal wires overhead. Why are all these parts made from metals? Which parts could be replaced by non-metallic materials?

Part 1 Production and prices

Production

Some metals are used much more than others. Table 1 shows the world production of metals in thousands of tonnes per year during the 1980s. The metals are listed in alphabetical order.

Look at Table 1, then answer questions 1 and 2.

Table 1 World production of metals during the 1980s. The table lists the nineteen metals produced in the largest quantities, in alphabetical order.

Metal	*Symbol*	*World production/thousand tonnes per year*
Aluminium	Al	12 700
Antimony	Sb	50
Arsenic	As	20
Chromium	Cr	6000
Cobalt	Co	30
Copper	Cu	8000
Gold	Au	1
Iron	Fe	400 000
Lead	Pb	3000
Magnesium	Mg	300
Manganese	Mn	8000
Molybdenum	Mo	100
Nickel	Ni	700
Silver	Ag	10
Tin	Sn	200
Tungsten	W	40
Uranium	U	40
Vanadium	V	30
Zinc	Zn	6000

Questions

1. *Which six metals are produced in the largest amounts? List them in order with the largest first.*
2. *Which of the metals in Table 1 is produced in the* smallest *amount? Suggest a reason why its production is small.*

Figure 2 Silver bars, 99.9 per cent pure. Worth about £5000 each at 1985 prices

Prices

The prices of metals vary widely. Table 2 gives the prices of a selection of important metals. The table also gives the percentage abundance of the metal in the Earth's crust. We might expect the most abundant metals to be cheapest.

Look at Table 2, then answer questions 3 to 5.

Table 2 Prices and percentage abundance of metals

Metal	*Price per tonne (1985)*	*Abundance (% of Earth's crust)*
Aluminium, Al	£750	8.1
Chromium, Cr	£3700	0.01
Copper, Cu	£1000	0.0055
Gold, Au	£8.6 million	0.0000004
Iron, Fe	£130	5
Lead, Pb	£290	0.0013
Silver, Ag	£150 000	0.000007
Tin, Sn	£9100	0.0002
Zinc, Zn	£500	0.007

Questions

3 *Arrange the metals in order of price, cheapest first.*

4 *Arrange the metals in order of abundance, most abundant first.*

5 *How well do the two lists from questions 3 and 4 match up? Are the least abundant metals generally the most expensive? Are the most abundant metals generally the cheapest? What important exceptions do you notice?*

The price of metals does not just depend on their abundance in the Earth's crust. Most metals occur combined, as **ores**. The metal has to be **extracted** from the ore before it can be used. The more reactive metals are more difficult and expensive to extract from their ores. In the following list, the metals in Table 2 are placed in order of reactivity, with the most reactive first:

Aluminium, Al
Zinc, Zn
Chromium, Cr
Iron, Fe
Tin, Sn
Lead, Pb
Copper, Cu
Silver, Ag
Gold, Au

Answer questions 6 to 10 on the next page.

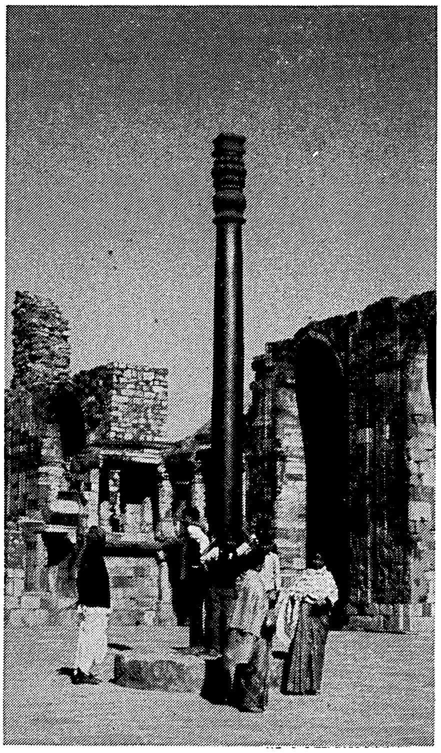


Figure 3 The Iron Pillar of Delhi. This remarkable piece of metalwork has stayed unrusted for over 1500 years.

Questions

6 *Does the list of metals in order of reactivity help to explain any of the exceptions you found in question 5?*

7 *Using Table 2 and the list that follows together, try to explain why:*
(a) gold is more expensive than silver
(b) aluminium is more expensive than iron
(c) copper is more expensive than aluminium

8 *Abundance and reactivity are not the only factors that affect the price of metals. What other factors do you think might be important?*

9 *Imagine a world in which gold and silver were cheap, but iron and aluminium were rare. What advantages and disadvantages would there be in (a) making a car from gold instead of iron; (b) making saucepans from silver instead of aluminium?*

10 *Aluminium is made from an ore called bauxite. A lot of bauxite comes from Jamaica. 75 per cent of Jamaica's exports are connected with bauxite. In the early 1980s, the recession in industrialized countries caused the price of aluminium to fall. This in turn caused unemployment and poverty in Jamaica. Explain why the fall in price of aluminium affected Jamaica in this way.*

Part 2 Reserves and resources

How much is left?

The amount of metal ores in the Earth's crust is limited. We cannot go on digging them up for ever. Sooner or later there will not be enough left to be worth mining.

It is difficult to say how long our supplies of metals will last. This is because we cannot tell exactly how much ore there is under the ground, and how pure it is. The amount of a metal ore which we *know* is worth getting out is called the **reserve** of that ore. Figure 4 shows how long reserves will last for certain metals. The figures assume the metals will go on being used at the same rate as at present.

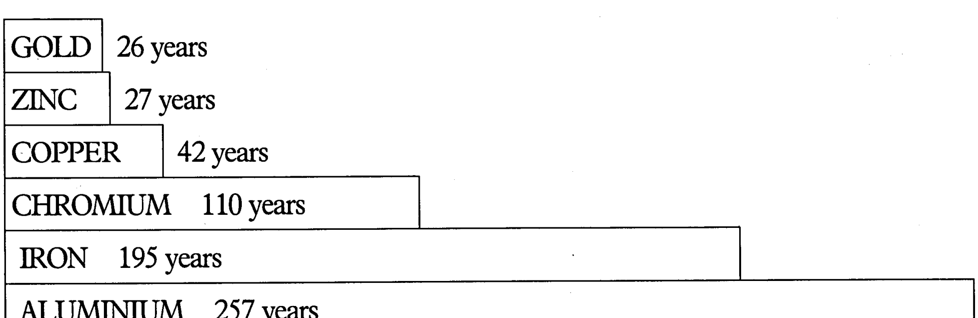


Figure 4 Lifetimes of reserves of some metals

The metals in Figure 4 should actually last longer than their reserve lifetimes. This is because there are probably supplies which we do not know about yet. The total supply of the metal, known and unknown, is called the **resources** of the metal. Figure 5 illustrates the difference between reserves and resources.

Answer questions 11 and 12.

Questions

11 Reserves of aluminium are very high. Explain why.

12 Reserves of metals may actually increase *with time, even though the metal is being used up. Suggest a reason why.*

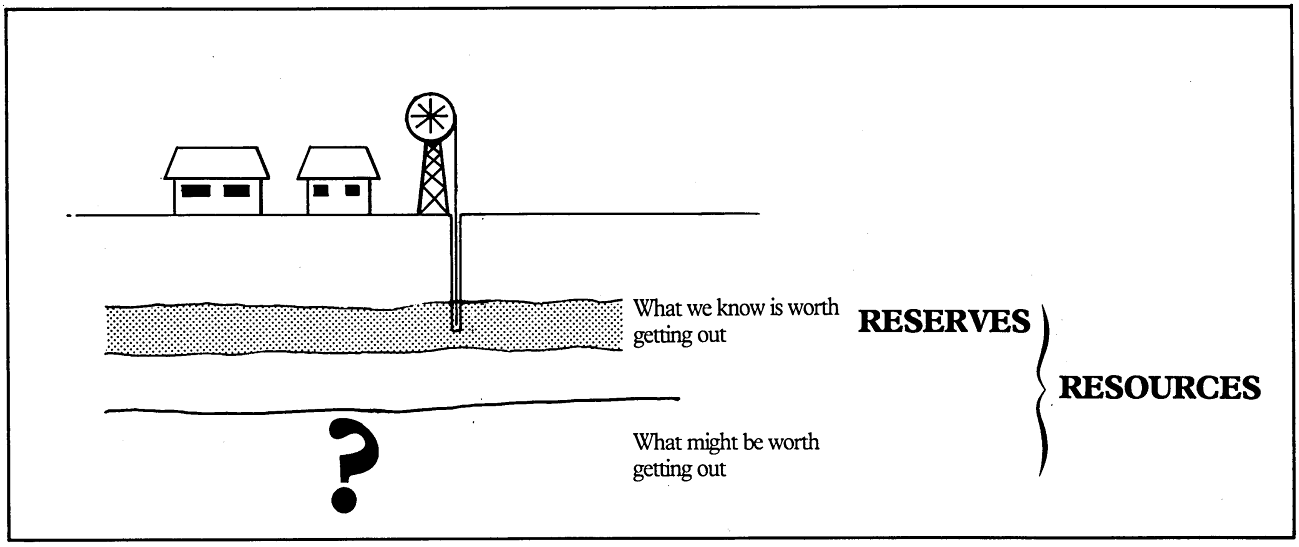


Figure 5 Reserves and resources

Part 3 What happens when supplies run out?

Even though new reserves of metal ores are constantly being discovered, supplies must eventually run out. Long before then, we will need to look for ways round the problem. There are two important ways round the metal supply problem:

1 Recycling used metal
2 Using other materials instead of metals.

1 Recycling

Recycling means melting metal down and using it again. We already recycle used metal. Over 90 per cent of all the gold we use gets recycled, though only 50 per cent of iron is recycled. We can do more to recycle metals now, and in the future we will have to.

2 Using other materials instead of metals

Scientists are already finding new materials to replace metals. For example, copper can be replaced by plastic in pipes, and by optical fibres in telephone wires (Figure 6). Steel can be replaced by concrete for many uses, and aluminium can be replaced by plastic. But it is important to remember that eventually the replacements themselves may run out. For example, plastics are made from oil, and supplies of oil are limited.

Answer questions 13 to 16.

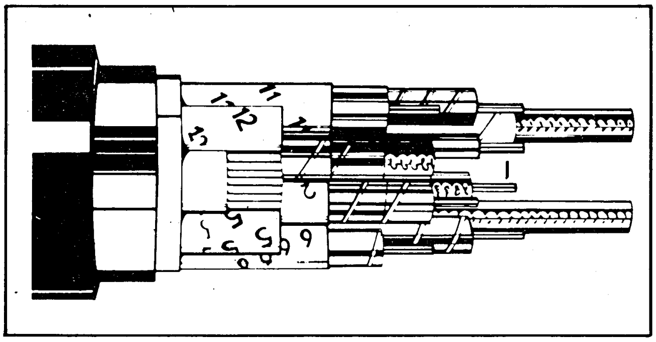
Questions

13 *Explain why practically all the gold we use is recycled, but only half the iron is recycled.*

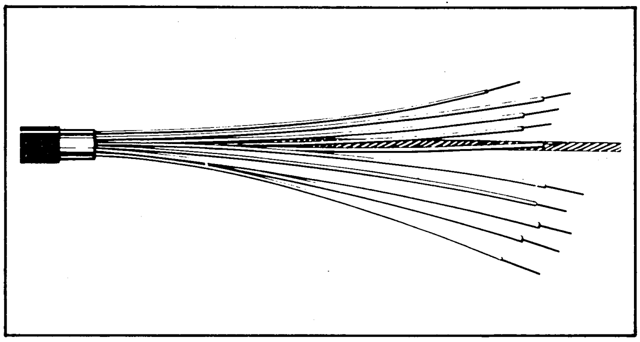
14 *What are the difficulties in recycling more of the iron we use?*

15 *For which uses do you think metals will be most difficult to replace?*

16 *Imagine world supplies of copper suddenly ran out. How would this affect your life?*



Telephone cable with 10 000 call capacity — made from copper



Telephone cable with 10 000 call capacity — made from optical fibre

Figure 6

The Great Chunnel Debate

Contents: Information, questions and debate concerning the building of a fixed Channel link.

Time: 2 periods or more, depending on the amount of time spent on the debate.

Intended use: GCSE Physics, Engineering Studies, Environmental Studies and Technology. Although not linked to any specific syllabus area, the unit illustrates a number of the economic, social and environmental issues associated with large engineering projects.

Aims:

- To describe the nature of fixed Channel link projects, in particular the Channel Tunnel
- To develop awareness of some of the economic, social and environmental issues associated with major engineering projects
- To explore some of the benefits and drawbacks of a fixed Channel link
- To provide opportunities to practise communication skills, in particular debating skills.

Requirements: Students' worksheets No. 605

The unit is in four parts:

Part 1 The advantages of a fixed Channel link
Part 2 The Channel Tunnel plan
Part 3 The case against the link
Part 4 The Great Chunnel Debate.

The first three parts comprise general information and questions concerning the building of a fixed Channel link. It should be noted that many different projects have been proposed over the years for a Channel tunnel or bridge. In 1986 the British and French Governments selected the proposal for a twin railway tunnel put forward by the Channel Tunnel Group. Other strong contenders included the Euroroute, a combined road/rail, bridge/tunnel scheme, and Channel Expressway, a proposal comprising two road tunnels and two rail tunnels.

Part 4 of the unit comprises a classroom debate. Having completed the first three parts, students should be reasonably familiar with the arguments for and against the tunnel. It is suggested that two groups should be created, one for and one against. The optimum group size would be four or five, but it will probably be necessary either to have larger groups than this, or to select a limited number of the class for group membership, the remainder making up the voting audience. It will also be necessary to decide how to conduct the debate. One approach would be to allow each group five minutes to present their case, followed by questions from the floor and then a vote. Groups may wish to elect a spokesperson, or to divide up the presentation between them.

Notes on some of the questions

Q.6 The advantages of a fixed link:
(a) Independent of weather
(b) Faster than ferries
(c) No transhipment of passengers and goods needed
(d) Safety considerations: there is always the risk of a ferry colliding with other shipping in fog, particularly as the ferries travel almost at right angles to the main shipping routes
(e) Possibilities for relieving road congestion
(f) Job creation during the construction period.

Q.7 If road traffic is involved, a bridge has the advantage that it needs no ventilation and is less tiring for drivers than a tunnel. But a bridge would be a potential hazard and constraint to shipping, particularly in fog. It would be less protected from the weather, and it would cost more (see note on Q.12).

Q.8 The maximum debt is £7500 million.

Q.9 The debt is paid off after 22 years.

Q.10 Two years after the debt is paid off the tunnel will have earned £200 million.

Students may wonder why the debt goes on increasing even after the tunnel has opened and has started to earn income. This is because initially it does not earn enough to compensate for the effect of accumulating compound interest. Later, as the income increases, the debt begins to be paid off faster than interest accumulates.

Q.11 This is naturally a matter of opinion and political belief. Most experts consider that at least limited financial guarantees to cover cancellation or delays are needed from both governments if the confidence of investors is to be retained. The EEC is a possible source of funding.

Q.12 In general, bridge projects are more expensive than a tunnel. The combined bridge/tunnel Euroroute project was costed at £6000 million in the 1984 Banks' report (compared with £2000 million for the tunnel).

Costs

The figures given for the projected costs of the project are taken from the report of five major banks, *Finance for a Fixed Channel Link*, published May 1984. The figures may well be at variance with those given by the promoters themselves. Naturally there is a great deal of uncertainty associated with any estimates of cost for a project such as this.

Further resources

Further information on the Channel Tunnel project can be obtained from: The Channel Tunnel Group, 28 Hammersmith Grove, London W6 7EN.

Acknowledgements Figure 1 BBC Hulton Picture Library; Figures 3 and 4 supplied by The Channel Tunnel Group; Figure 6 supplied by Sealink British Ferries.

THE GREAT CHUNNEL DEBATE

Dover Strait is a shallow stretch of busy seaway between the English Channel and the North Sea. The weather often plays havoc with shipping services across the Strait. Many projects have been proposed for a fixed Channel link above or below the waves.

One of the first plans, in 1802, was for a tunnel for horse-drawn traffic. In 1880 a tunnel was actually started. It was stopped because people were afraid it could be used for invasion. In 1974, another tunnel was begun, but abandoned in 1975 for lack of money. In 1986, the British and French governments agreed to allow a railway tunnel to be built. But did they make the right decision? In this unit we will look at some of the arguments for and against.

The unit is in four parts:

- Part 1 The advantages of a fixed Channel link
- Part 2 The Channel Tunnel plan
- Part 3 The case against the link
- Part 4 The Great Chunnel Debate.

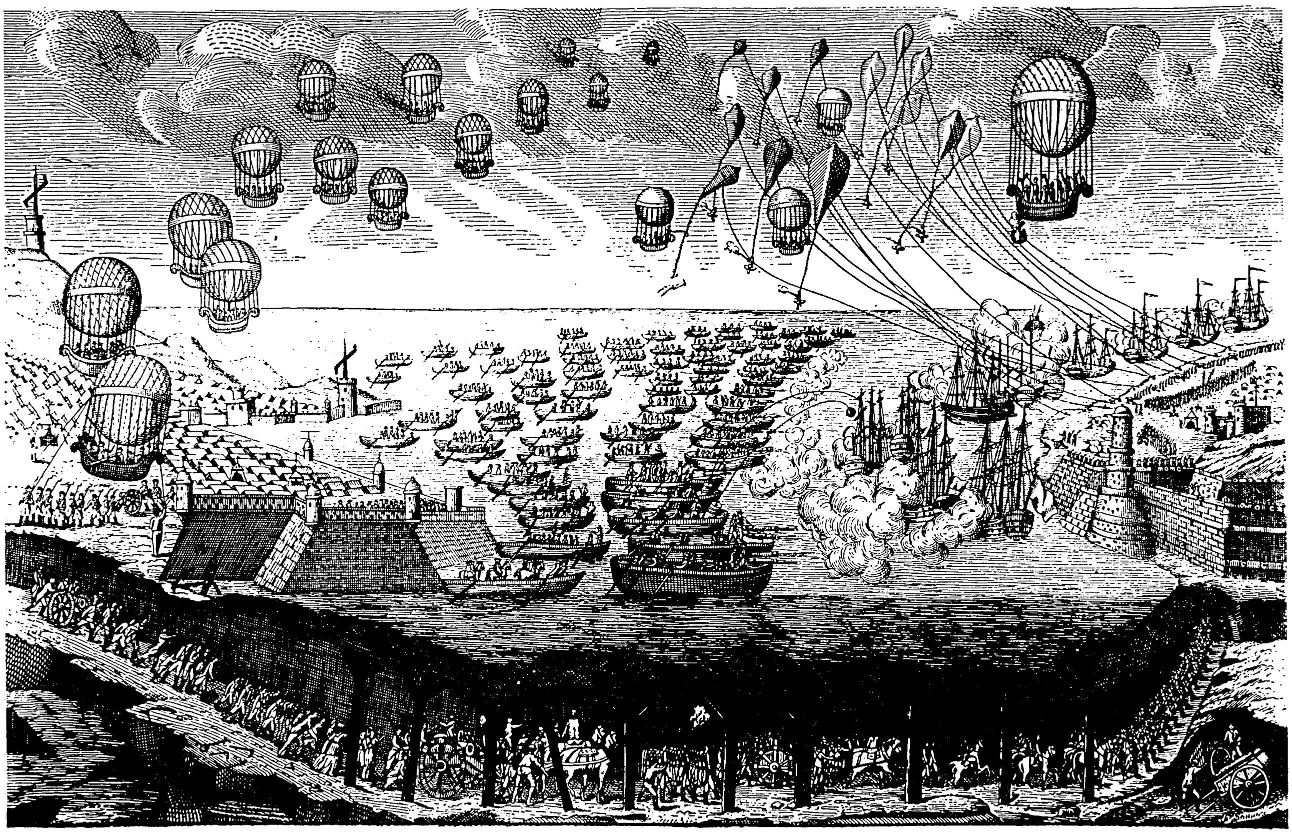


Figure 1 This picture, drawn in 1803, shows an imaginary invasion of England by Napoleon's soldiers by sea, air and Channel tunnel.

Part 1 The advantages of a fixed Channel link

Since joining the European Economic Community in 1973, Britain has become much more involved with mainland Europe. Nearly half of Britain's trade is with European countries like France, Germany and Italy. At the moment, goods going to and from Europe have to be loaded and unloaded onto Channel ferries. The same is true of passenger journeys.

A fixed Channel link, whether a bridge or a tunnel, would greatly improve trade links between Britain and the Continent. Travel would be faster and much easier. The link would be independent of the weather. Building the link would be an enormous project, and the main problem is how to pay for it. However, it would provide jobs for thousands of people.

Before you go any further, tackle questions 1 to 7. For the time being, forget that a decision has been made to build a tunnel. Decide what *you* think is best.

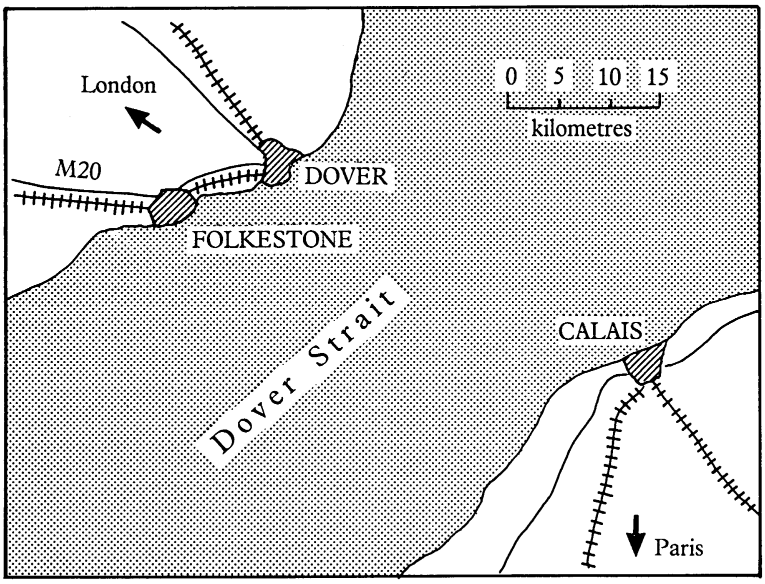


Figure 2 Dover Strait

Questions

1. *Make a rough copy of the map of Dover Strait shown in Figure 2.*
2. *What is the shortest distance between England and France, in kilometres?*
3. *Now choose what you think is the best route for a fixed cross-Channel link. You will need to consider the position and ease of access for existing roads and railways. Carefully draw the route on your map.*
4. *What* type *of fixed link do you think would be best (for example, tunnel, bridge or combination)? Give your reasons.*
5. *Will your link carry a road, a railway or both? Give your reasons.*
6. *What advantages would your scheme have over existing air and sea services, including hovercraft?*
7. *Compare the advantages of (a) a bridge and (b) a tunnel.*

Part 2 The Channel Tunnel Plan

Many different schemes have been suggested. The one accepted by the British and French governments was for a twin railway tunnel (Figure 3 on the next page).

Two railway tunnels would be bored through a layer of chalk 40 metres below the sea bed. This chalk is easy to bore through, and it runs evenly from coast to coast. It is impervious — it does not let water in. Laser-guided machines would be used to bore the tunnels.

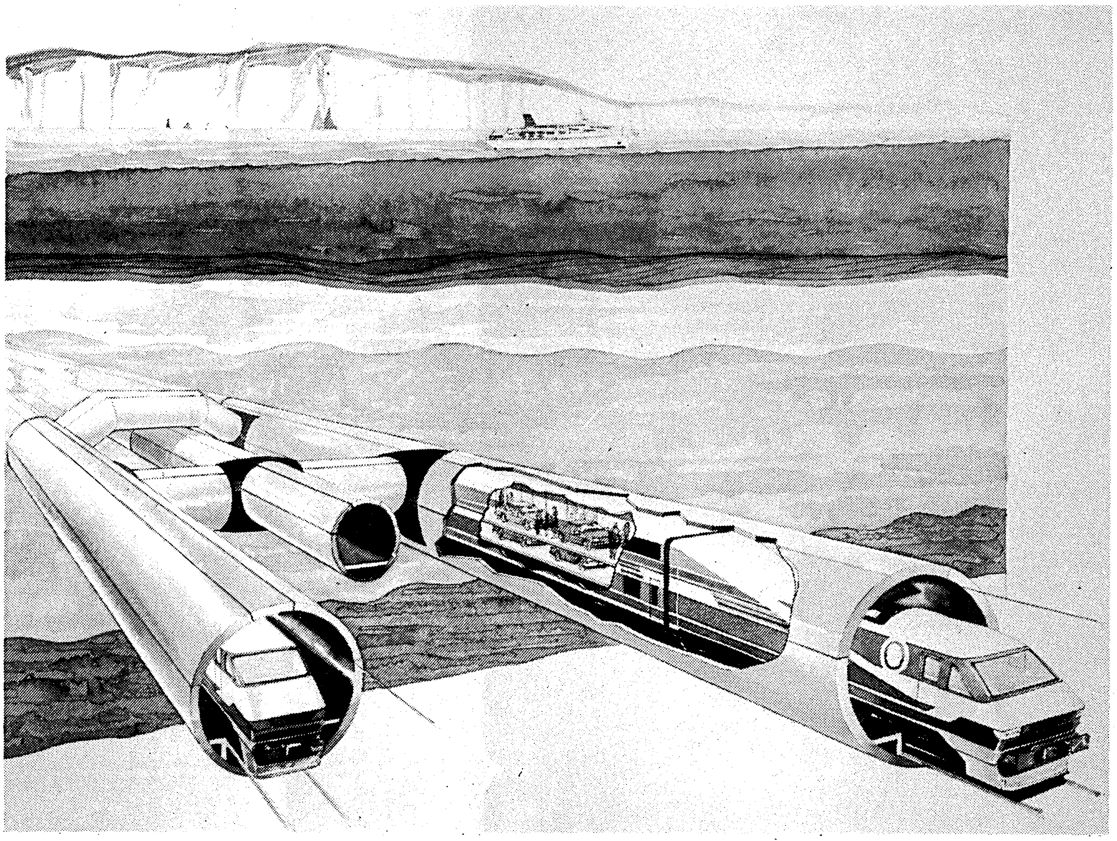


Figure 3 The twin railway tunnel. Length 50km, with 37km under the sea.

Road traffic would be carried by ferry trains. The trains would travel at up to 160 km/hour, and crossing time would be 25 minutes. Vehicles would be loaded onto the ferry trains at terminals at each end of the tunnel. Many goods could be carried by container. The big containers can be quickly loaded from lorries onto trains, then back onto lorries.

Through train services would operate between London and Paris, Lille or Brussels. There would be onward connections to other European cities. The journey time from London to Paris would be about four hours. This is less than half the present time. French Railways (SNCF) have planned a new high-speed track linking the tunnel to Paris. High-speed trains might be able to do the journey from London to Paris in as little as two hours.

Freight and goods could be carried from Britain to many European cities very quickly. For example, Scotch whisky could travel from Glasgow to Geneva in Switzerland in 36 hours.

It would be necessary to build large terminals for the loading and unloading of road vehicles (see Figure 4 on the next page). Most of the work would go on underground. The rock and other material removed from the tunnel could be used to build earthworks for the terminals. It could also be used in other projects, such as sea barriers. An environmental advantage would be that a lot of heavy road traffic would be diverted to rail. The tunnelling work would generate thousands of jobs in the Dover area. More jobs would be created in other parts of Britain, to supply machines and materials for the project.

Figure 4 Model of Channel Tunnel Terminal at Cheriton, near Folkestone, Kent

How much will it cost?

In 1984 the British government said it would not spend public money on any Channel link project. This means the money has to be borrowed privately — from banks and shareholders. Interest would have to be paid to the people who lent the money. This interest would build up and add to the total size of the loan. The loan would not be paid off until the project had earned enough income. Income would be earned by charging tolls for traffic using the tunnel. Table 1 gives possible cost and income figures for the tunnel.

Table 1 Possible cost and income for the Channel Tunnel

Cost to build	£2000 million
Time needed to build	7 years
Size of debt at time of opening	£6500 million
Expected yearly income (after deducting running costs):	
at time of opening	£100 million
25 years after opening	£320 million

The graph in Figure 5 on the next page shows how the debt would change over the years. Notice the way the debt builds up, due to interest, then drops, due to repayment from income.

Use the graph and Table 1 to answer questions 8 to 11.

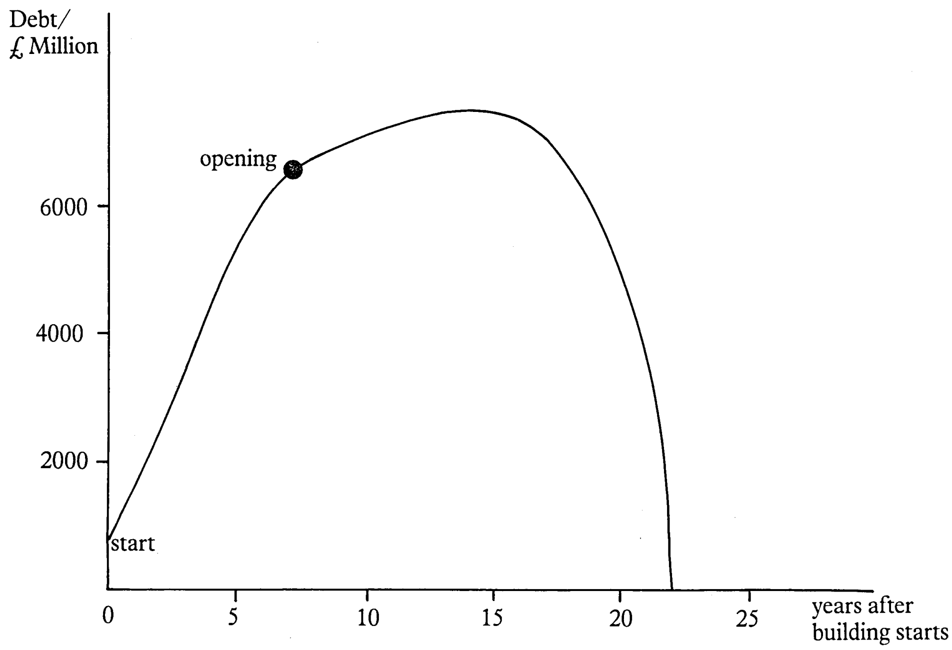


Figure 5

Part 3 The case against the link

There are a number of objections to building a Channel Tunnel. Some of these are given below.

- *Finance* The Channel Tunnel would cost billions of pounds. Would this money be better spent on other projects?
- *Do we need it?* Dover Harbour Board already operates the world's largest ferry port. Ferry services from Dover could be expanded still further. There are cross-Channel services from other ports too (Figure 7 on the next page). It would be possible to develop these other ports, creating employment in areas other than the South East. Developing cross-Channel ferries in this way could make the Channel Tunnel unnecessary.

Questions

8 *What is the size of the maximum debt?*

9 *How long after the start of building will it be before the debt is completely paid off?*

10 *How much income will the tunnel have earned one year after the debt has been paid off?*

11 *Do you think a Channel link project should be paid for out of public money or out of private money? Give reasons for your answer.*

Figure 6 A cross-Channel car ferry

- *Flexibility* Ferry services are more flexible than a tunnel. They could easily adapt to future trends in cross-Channel transport. A tunnel, once built, could not be changed.
- *Environmental problems* Large terminals would have to be built at each end of the tunnel. These would take up a lot of land and change the local landscape. There would be 4 million cubic metres of rock and spoil removed from the tunnel to get rid of.

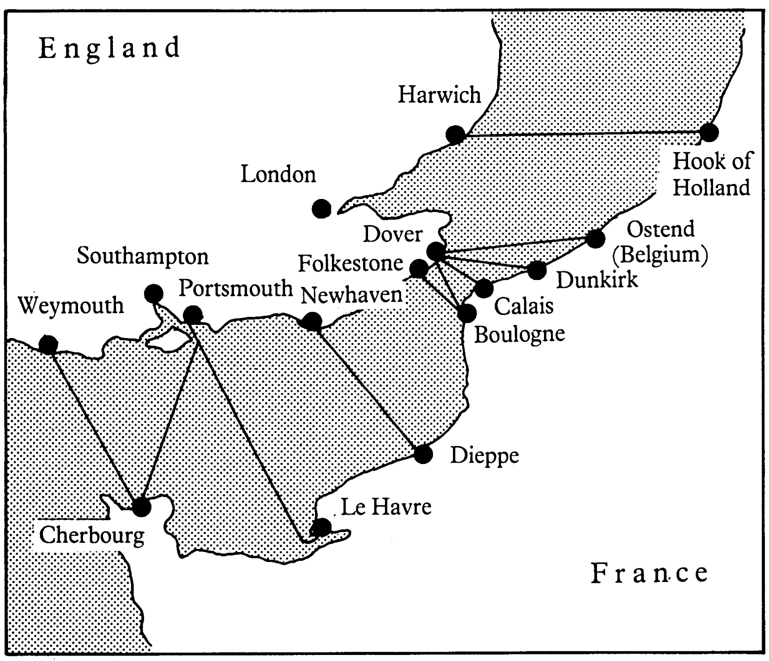


Figure 7 Some ferry services between England and Europe

- *What happens if the tunnel has to close?* This might happen temporarily from time to time, for example, because of accidents. Closure would cause enormous traffic jams if the tunnel was the main route to Europe.

- *Sabotage* A tunnel would be vulnerable to sabotage. For example, terrorists might threaten to blow it up or block it.
- *Cost and time over-run* It is very difficult to estimate how much a project like this would cost, or how long it would take to build. It is quite likely that the project would cost more, and take longer, than estimated. An example of this occurred with the 22-kilometre tunnel between Japan's two main islands. It was seven years behind schedule and cost three times more than estimated.

Answer questions 12 to 15.

Questions

Suppose there had been a decision to build a bridge *instead of a tunnel.*

12 *Would a bridge cost more or less than a tunnel, do you think?*

13 *Would a bridge provide better services than a tunnel?*

14 *Would a bridge be more or less vulnerable to sabotage?*

15 *Would a bridge cause more or less environmental problems?*

Part 4 The Great Chunnel Debate

In this part you will be debating and voting for or against building the Channel Tunnel.

There will be two groups, one for and one against.

Each group should prepare its case carefully, using the information earlier in the unit.

You should consider:

(a) the quality and convenience of services offered
(b) the cost
(c) the employment generated or lost
(d) the environmental advantages and disadvantages
(e) the long-term prospects

and any other important features.

Each group will have a chance to present its case to the class. There will be opportunities to question the two groups. Then a vote will be taken to decide for or against the Channel Tunnel.

The Tristan da Cunha Dental Surveys

Contents: A data analysis exercise concerning the effect of diet on dental decay.

Time: 1 to 2 periods.

Intended use: GCSE Biology and Integrated Science. Links with work on teeth and tooth decay.

Aims:

- To complement work on teeth and tooth decay
- To show the link between tooth decay and diet
- To illustrate the use of scientific evidence
- To provide opportunities to practise skills in data analysis.

Requirements: Students' worksheets No. 606. Graph paper.

This simple exercise shows strikingly the link between dental decay and dietary factors. It also highlights the problem of drawing conclusions from surveys of human populations. The population of Tristan da Cunha up to 1961 was almost unique in its isolation and its freedom from complicating factors such as migration and changes in environment, and the survey provides powerful evidence for the role of refined foods, notably sugar, in causing tooth decay.

The survey data is taken from *New Scientist*, January 1982.

Acknowledgement Figure 2 reproduced by courtesy of Allan B. Crawford, FRGS.

THE TRISTAN DA CUNHA DENTAL SURVEYS

Tristan da Cunha

Tristan da Cunha is a small volcanic island in the middle of the South Atlantic (Figure 1). It is one of the loneliest places in the world.

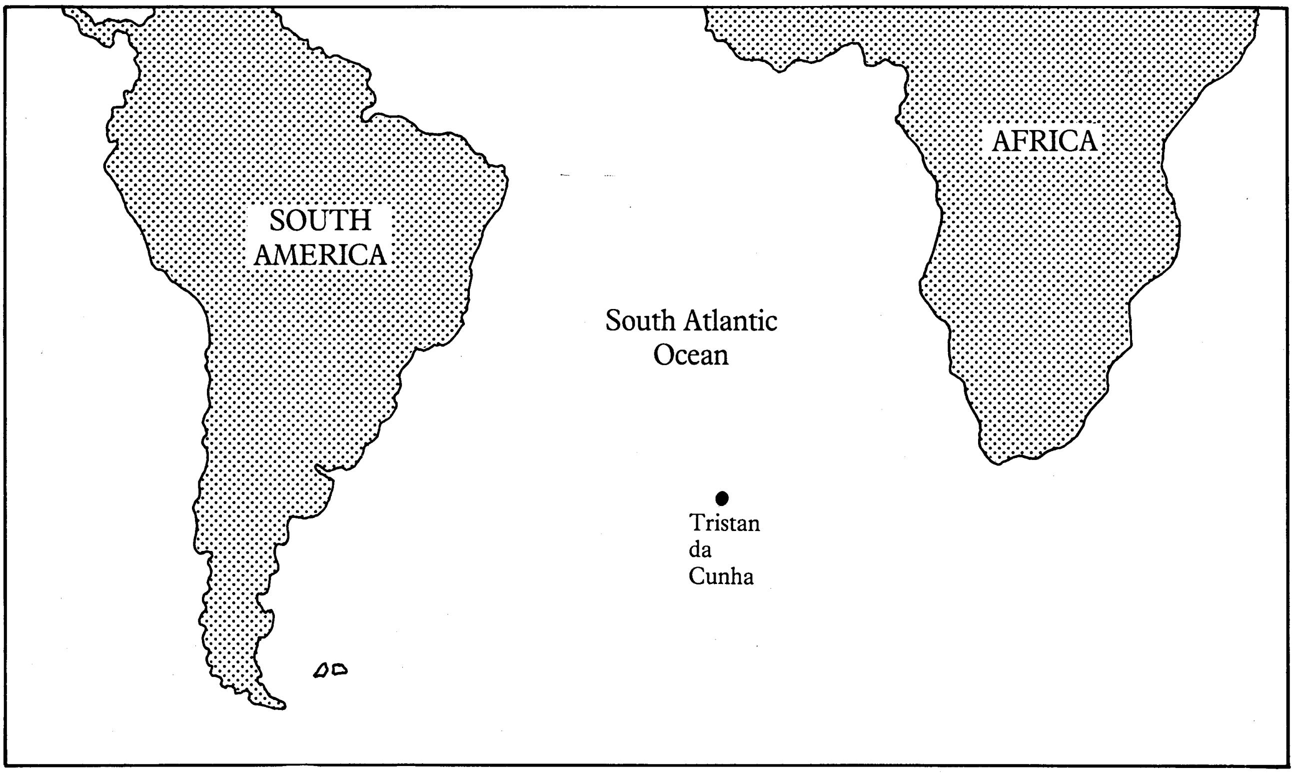


Figure 1 A map showing the position of Tristan da Cunha

The original inhabitants of the island were shipwrecked sailors. By 1880 there were 109 people living on the island. Their food supply came from fishing, from a few animals such as cattle and hens, and from vegetables. The main food was potatoes.

As the twentieth century progressed communications improved. The islanders began to develop products for sale. In 1949 a crawfish company began operations on the island, and opened a canning factory. The islanders began to have more money to spend. This led to a change of diet as increasing amounts of refined food were imported.

On 23 October 1961 the volcano, which was thought to be extinct, erupted. The whole population was rescued and settled temporarily in Britain. In 1963 they returned and resettled in Tristan da Cunha. The population in 1982 was 325.

The dental surveys

Until 1961, the population of Tristan da Cunha had a relatively fixed genetic pattern and a constant environment. This provides an ideal opportunity to study the effects of changes in the environment.

Between 1932 and 1955, four dental surveys were carried out by Dental Officers from the Royal Navy. They examined the islanders' teeth for signs of decay. The results of the survey are given in Table 1.

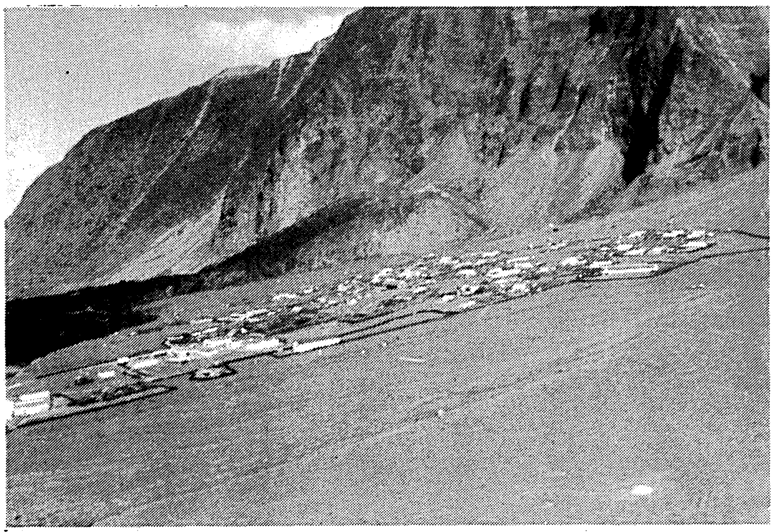


Figure 2 This aerial view shows the village of Edinburgh on Tristan da Cunha. Behind the village is the volcano which erupted in 1961.

Table 1 Results of the Tristan da Cunha dental surveys

Date of survey	*Percentage of teeth examined that showed decay*	*Percentage of people completely free from decay*	*Conditions and diet*
1932	1.8	83.3	A home grown diet of eggs, milk, fish, meat, potatoes and a few other vegetables. There was no bread or cakes. Sugar, tea, coffee and cocoa were novelties.
1937	4.2	50.2	Standard of living had improved. Scones and bread were made on several days in the week and always on Sunday.
1952	9.1	22.2	Islanders had begun to work for money at the crawfish canneries. A week's grocery order for the 230 islanders included 124 kg of sugar, 188 kg of flour and 46 kg of jam.
1955	12.6 (these figures are similar to those obtained in European countries at the same time)	12.4	Consumption of sugar had risen to 223 kg per week and flour to 528 kg. Jam had dropped a little but was replaced by chocolate, icing sugar and sweets.

Questions and activities

1 *Explain why, until 1961, Tristan da Cunha had a 'relatively fixed genetic pattern and a constant environment'.*

2 *Explain why this was no longer true after 1961.*

3 *Explain why the population of Tristan da Cunha provided 'an ideal opportunity to study the effects of changes in the environment'.*

4 *Plot a graph of the percentage of teeth that showed decay against the date of the survey. Put the date along the horizontal axis.*

5 *Plot a graph of the percentage of people completely free from decay against the date of the survey. Put the date along the horizontal axis. (You could use the same set of axes as for question 4, though you might need to use a different scale for the vertical axis.)*

6 *What do the results of the survey suggest?*

7 *Suppose a similar survey had been carried out on the same dates on a population of 200 people in a village in Britain. Would the results have been as useful as the results of the Tristan da Cunha survey? Explain your answer.*

8 *Suggest a reason why no surveys were carried out between 1937 and 1952.*

9 *Use your graph to estimate the number of people who were completely free from tooth decay in 1945.*

10 *Use your graph to estimate the percentage of people who were completely free from tooth decay in 1985. Explain how you got your answer.*

11 *Using your own knowledge, and if necessary a biology textbook, write two or three sentences on 'Dental decay and its causes'.*