How Safe is Your Car?

Contents: Reading and questions on road safety, with particular reference to the MOT test and brakes, tyres and seat belts.

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

Intended use: GCSE Physics and Integrated Science. Links with work on motion, friction and energy.

Aims:

- To complement and revise work on velocity, acceleration and Newton's Laws of Motion, and work on friction and energy conversion
- To develop awareness of the MOT road vehicle test, its nature and limitations
- To develop awareness of certain features of safe road use
- To provide opportunities to practise skills in investigation, reading and comprehension.

Requirements: Students' worksheets No. 504

This unit is in three parts.

Part 1 *The MOT test* is introductory and looks at a number of car safety features
Part 2 *Trying to stop in time*... is about brakes and tyres
Part 3 *If you don't stop in time*... is about seat belts.

The three parts are independent and can be used separately, although Part 1 makes a useful introduction to the other two.

Notes on some of the questions

Qs 1 to 4 The MOT (Ministry of Transport) test must be taken annually by cars over three years old. In 1985 the fee for a successful test was £10.70. A failure also costs £10.70, but there is no extra charge for a successful retest, provided the necessary repairs are carried out by the garage doing the test.

Q.6 *The MOT Tester's Manual* (from HMSO, price £3.95 in 1985) gives details of the testing procedures. The efficiency of the parking brake (hand brake) and service brake (foot brake) are tested on a rolling brake tester. Metal rollers rotate the vehicle's wheels. The brake is applied, and the machine records the braking force exerted on the rollers.

Q.8 Seat belts are examined for cuts and signs of deterioration. The security of the mountings and the operation of the locking mechanisms are also checked.

Q.9 A major shortcoming of the MOT test is that it is conducted only once a year. Faults develop over short periods, and an annual test can only pick them up by luck, or some time after they have developed. For example, 1mm of brake lining may give good results on the day of the test, but not a week later. The test is in any case fairly superficial: it would be difficult to introduce a more thorough test without a substantially increased fee. The AA estimate that MOT tests cost motorists at least £250 million each year, and they believe that, in terms of cost-effectiveness, this money might have been better spent on different road-safety measures. It is estimated that only 8 per cent of accidents can be attributed to vehicle defects. The majority are caused by human error: 95 per cent of all reported injury accidents on the road result primarily from driver error.

Qs 10 and 11 Power-assisted brakes are used to provide the large braking force needed on heavy or high speed vehicles. On cars, they are usually activated by vacuum from the inlet manifold. On lorries, the brakes are usually activated by compressed air.

Q.14

	Thinking distance	*Stopping distance*
Rain	Unchanged (but visibility may be reduced)	Increased
Tired driver	Increased	Unchanged or increased
Alcohol	Increased	Unchanged or increased
Icy road	Unchanged	Greatly increased
Fog	Unchanged, but visibility reduced, so less time to react	Unchanged, or increased if road is wet

With suitable students, the figures on thinking and stopping distances could be handled more quantitatively, using the question below.

This table gives figures for thinking and breaking distances at different speeds.

Speed/km per hour	*Thinking distance/m*	*Braking distance/m*	*Total stopping distance/m*
40	7	8	15
50	9	13	22
60	11	20	31
80	15	34	49
100	19	54	73

(a) Use the figures in the table to plot graphs of:
  (i) Thinking distance versus speed,
  (ii) Braking distance versus speed.

(b) What is the mathematical relationship between:
  (i) Thinking distance and speed,
  (ii) Braking distance and speed?

(c) Try to explain the relationship between:
  (i) Thinking distance and speed,
  (ii) Braking distance and speed.

Answers:

(b) (i) Thinking distance is proportional to speed.
  (ii) Braking distance is proportional to the square of speed.

(c) (i) Assuming thinking *time* is fixed, the *distance* travelled by the car will be proportional to its speed.
  (ii) This follows from the formula $v^2 = u^2 + 2as$, assuming the deceleration is constant.

Q.16 With a tight belt, there is a longer distance over which the stretching of the belt can decelerate the passenger. In addition, with a loose belt there will be a sudden 'snatch' as the passenger moves forward into the belt.

Qs 17 and 18 Wide seat belts ensure a smaller force per unit area. The pressure is applied to parts of the body well able to withstand it, namely the thorax and pelvis.

Q.19 The cut in the belt reduces its cross-sectional area and since the force in the belt is constant, the tensile stress at this point is increased. This results in greater stretching, and possible failure at this point.

Q.20 A belt which has been involved in a collision becomes permanently stretched and will no longer perform satisfactorily. It may also have fabric damage within the locking unit which would not be apparent without stripping the assembly down.

Q.21 Rear seat passengers are less frequent than those in front seats, and until 1986 it was not compulsory for new cars to be fitted with rear seat belts. However, in the years following the introduction of compulsory front seat belt wearing, the number of deaths of rear seat passengers increased, and there was pressure to make rear seat belts compulsory as well. It seems unlikely that compulsory rear seat belt wearing will be introduced until the majority of cars are fitted with them.

Further work

A good deal of practical laboratory work associated with this topic is possible. For example:

1 (a) Brakes and deceleration: see Nuffield Science 13-16, *Cars on the Move.*

(b) Seat belts: experiments using eggs and egg-boxes (from RoSPA (The Royal Society for the Prevention of Accidents) project 'Seatbelt Science'). Fix an egg box to a trolley using rubber bands. Using an egg as a 'passenger', and with the lid on the box, run the trolley down an inclined plane into a rigid 'crash barrier'. It will be found that the 'passengers' can survive quite severe collisions. Repeat with no top on the egg box to simulate the (messy) effect of a passenger being 'thrown clear' in the collision. Ticker tape can be attached to the trolley to measure collision speed, and the effects of different size egg 'passengers' could be investigated.

2 If time permits, students could also investigate other safety features of cars, for example:
Headrests — why do they improve safety?
Steering column, rear view mirror, sunvisors, dashboard, etc. — why are they hazards, and how are the hazards minimized?
Front and rear lights — how do they improve safety, and what checks are made on them in the MOT test?

Further resources

1 RoSPA (The Royal Society for the Prevention of Accidents) has a wide range of material, including films, relating to safety matters in general and road safety in particular. Catalogue available from: Safety Education, RoSPA, Cannon House, The Priory Queensway, Birmingham B4 6BS.

2 The Transport and Road Research Laboratory have useful reports and leaflets relating to car safety. From: TRRL, Old Wokingham Road, Crowthorne, Berkshire RG11 6AU.

3 The Granada TV series *Physics in Action* includes a useful programme entitled *Laws of Motion 1*, which contains sequences relating to braking and seat belts. The programme can be recorded off-air for school use. Transmission times can be found in the ITV for Schools programme schedule.

Acknowledgements Figure 1 supplied by John Van Dyk; Figure 2, Department of Transport; Figure 4 reproduced by permission of the Controller of Her Majesty's Stationery Office; Figure 5 supplied by the Transport and Road Research Laboratory (Crown Copyright).

HOW SAFE IS YOUR CAR?

Each year about a quarter of a million road accidents are reported to the police. Over five thousand people are killed in these accidents. Road accidents have many causes. Drivers and pedestrians make mistakes, particularly after drinking alcohol. In fact, in 95 per cent of all road accidents, the driver is at least partly to blame. But one cause of accidents is the condition, or 'roadworthiness', of the vehicle. In this unit you will be looking at some of the features affecting the roadworthiness of a car. The unit is in three parts:

Part 1 *The MOT test*
Part 2 *Trying to stop in time . . .*, about brakes and tyres
Part 3 *If you don't stop in time . . .*, about seat belts.

Part 1 The MOT test

The 'roadworthiness' of a car is checked when the vehicle is put in for the MOT test. Try to find the answers to questions 1 to 5 about the MOT test. You may have to visit a garage which does MOT tests in order to answer them all.

Questions

1 *What does MOT stand for?*

2 *How often does a car have to have an MOT test?*

3 *At what age does a car have to have its first MOT test?*

4 *How much does an MOT test cost?*

5 *If someone you know recently put a car in for an MOT test, find the answers to these questions:*
(a) Did the car pass or fail?
(b) If it failed, what did it fail on?
(c) If it failed, what needed to be done before it passed?

Figure 1 An MOT testing centre

The MOT check-list

Figure 2 shows the check list which is used by MOT testers. Each item on the list has to be checked. If any item fails, the car fails the MOT. Look at the check list, then answer questions 6 to 9.

Questions

6 Section III
(a) What is the difference between the service brake and the parking brake?
(b) How do you think they test the efficiency of the brakes?

7 Section IV
Why is the condition of the tyres important to the safety of the car?

8 Section V
What particular features do you think the testers look for when they inspect the condition of seat belts?

9 *What are the limitations of the MOT test as a way of improving road safety?*

Figure 2 The MOT Check List

Department of Transport

Check List for Vehicle Inspection

CUSTOMER'S COPY

VT 29
(Revised June 1983)

Vehicle Reg. No. or Chassis No. .... Make & Model .... Approx. year of manufacture .... Recorded mileage ....

Code	Testable Item	Testers Manual Reference. (See Note below)	Pass	Fail	Remarks
01	**Section I – Lighting Equipment**				
02	Oblig. Front Lamps	I/1			
03	Oblig. Rear Lamps	I/1			
04	Oblig. Headlamps	I/2			
05	Headlamp Aim	I/6			
06	Stop Lamps	I/3			
07	Rear Reflectors	I/4			
08	Direction Indicators	I/5			
09					
10	**Section II – Steering & Suspension**				
11	Steering Controls	II/1			
[redacted]	Steering Mechanism	II/2			
	Power Steering	II/3			
	Transmission Shafts	II/2.2.15,II/4.4			
15	Stub Axle Assemblies	II/5			
16	Wheel Bearings	II/4			
17	Suspension	II/5,6,7,8,9.			
18	Shock Absorbers	II/10			
19					
20	**Section III – Braking System**				
21	Service Brake Condition	III/3,4			
22	Parking Brake Condition	III/1,2			
23	Service Brake Efficiency	III/5,6,7,8.			
24	Parking Brake Efficiency	III/5,6,7,8.			
25	Service Brake Balance	III/5,6,7,8.			
26					
27	**Section IV – Tyres & Wheels**				
28	Tyre Type	IV/1			
29	Tyre Condition	IV/1			
30	Roadwheels	IV/2			
31					
	Section V – Seat Belts				
	Security of Mountings	V/1			
34	Condition of Belts	V/1			
35	Operation	V/1			
36					
37	**Section VI – General Items**				
38	Windscreen Washers	VI/1			
39	Windscreen Wipers	VI/2			
40	Horn	VI/4			
41	Condition of Exhaust System	VI/3			
42	Effectiveness of Silencer	VI/3			
43	Condition of Vehicle Structure	VI/5			
44					

During the test on this vehicle the defects mentioned below were noticed, which in the opinion of the tester, render the vehicle DANGEROUS for use on the road:-

Warning: A person who drives a dangerously defective vehicle on the road is liable to prosecution and the insurance may not be operative.

Note: The MOT Testers Manual is a comprehensive guide to the inspection procedures applied during the MOT test. It sets out in detail the statutory requirements that vehicles have to meet, the methods of inspection and the principal reasons for failure. The manual may be purchased from Her Majesty's Stationery Office or through any bookseller.

Pass Cert. No. .... Fail Cert. No. ....
(VT 20) (VT 21 or VT 22)

Signature of Tester ....Date of Test ....

Testing Station No. ....

Printed in U.K. for H.M.S.O. 8840212 10/84 9830

Part 2 Trying to stop in time . . .

Most MOT failures are because of unsafe tyres and brakes. Tyres and brakes are essential for stopping the car quickly and safely.

When a car stops, it **decelerates**. For the car to come to a stop quickly, the deceleration needs to be high. Now, in order to give a body of mass **m** an acceleration or deceleration **a**, we need to exert a force **F** on it, where

$$\mathbf{F} = \mathbf{ma}$$

The force **F** is a frictional force. It is exerted on the wheel by the brakes, and on the road by the tyres. If a car is to stop quickly, the deceleration must be large, so **F** will need to be large too. If the car (or lorry) is heavy, **F** will need to be even larger.

So, for safe stopping you need brakes that work efficiently and exert a large frictional force on the wheel. Figure 3 shows how car brakes work.

Questions

10 What are power-assisted brakes?

11 Why do all lorries and most large cars have power-assisted brakes?

12 When brakes are beginning to wear out, they often start to 'pull' the car to one side. Why is this?

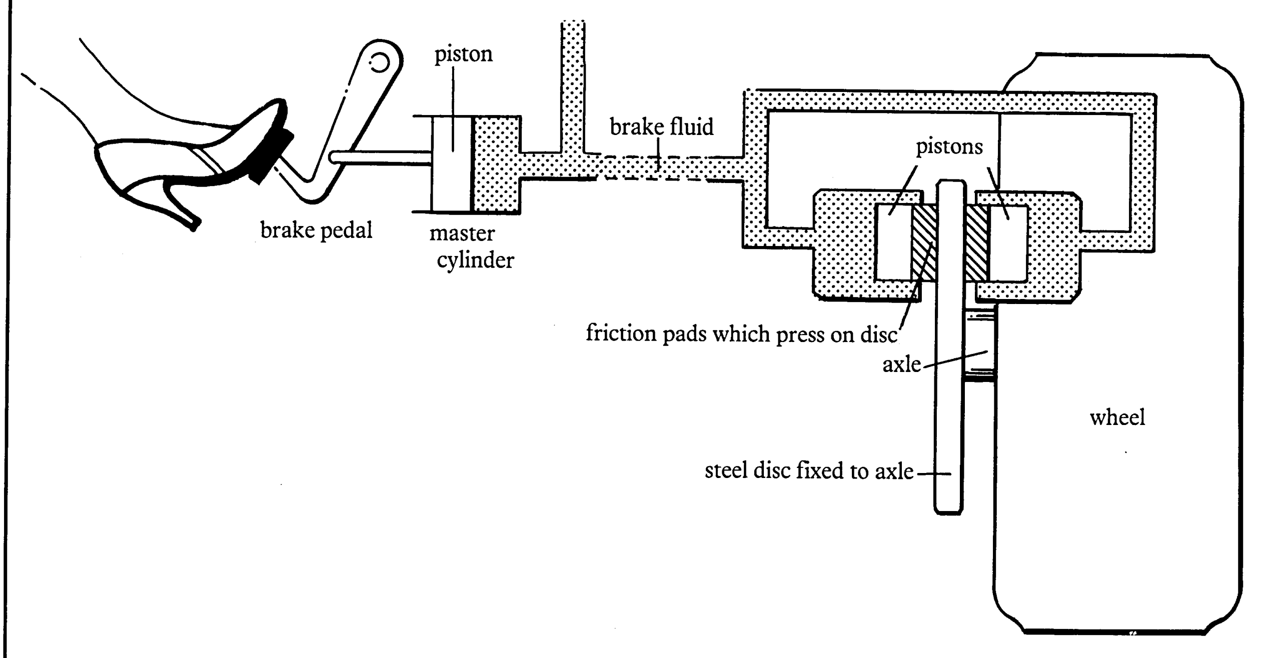

Figure 3 How car brakes work. When the brake pedal is pushed down, the piston in the master cylinder puts pressure on the brake fluid. This pressure is transmitted to the wheel cylinders, where it pushes the friction pads against the disc.

Safe stopping also requires tyres to keep a grip on the road. This 'grip' is the frictional force between tyre and road. If the tyres slip (skid) over the road, the force they exert on the road becomes smaller. This means the car takes longer to stop. Water lubricates the tyre and the road, making the frictional force less. To avoid this, tyres have *treads* which help clear water from under the tyre. If these treads are worn, the tyre becomes particularly dangerous in wet weather.

Stopping distances

Figure 4 is taken from the Highway Code. It shows the distances needed to stop when travelling at different speeds. The distances are for a well maintained car in good weather conditions.

Notice that the stopping distance is made up of two parts:

1 *The thinking time* It takes a little time between a person seeing that something has to be done, and the muscles actually doing it. During this time, the car moves through the thinking distance.

2 *The braking distance* This is the distance the car travels between applying the brakes and coming to a stop.

Answer questions 13 to 15.

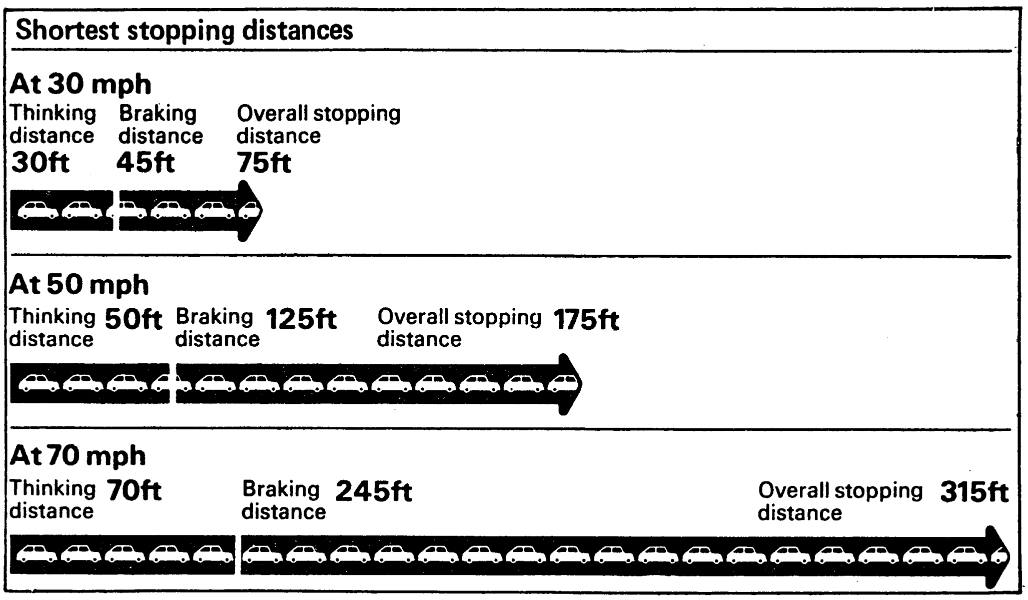

Figure 4 Shortest stopping distances (from Highway Code)

Questions

13 When a car uses its brakes to come to a stop, it loses all its kinetic energy. What is this energy changed to? Where does the change take place?

14 The stopping distances in Figure 4 are for an alert driver, in a good car with good brakes and tyres, on a dry road. What difference will each of the following make to: (a) the thinking distance;
(b) the stopping distance?
(i) Rain
(ii) A tired driver
(iii) A driver with alcohol in his or her blood
(iv) Icy road
(v) Fog.

15 In foggy weather, giant 'motorway pile-ups' are quite common. Cars run into the back of one another. Sometimes hundreds of vehicles are involved. How could these pile-ups be prevented?

Figure 5 This close-following warning sign lights up automatically if vehicles are travelling too close together.

Part 3 If you don't stop in time . . .

Sometimes, the brakes and tyres of a vehicle do not stop it in time. The result is a crash, and the people inside may be badly hurt or even killed. Modern cars are designed to reduce crash injuries as much as possible. The car is designed to 'crumple' at the front and rear, but leave the 'passenger cell' intact (Figure 6). (This is why you should never carry passengers in the luggage area of an estate or hatch-back car.)

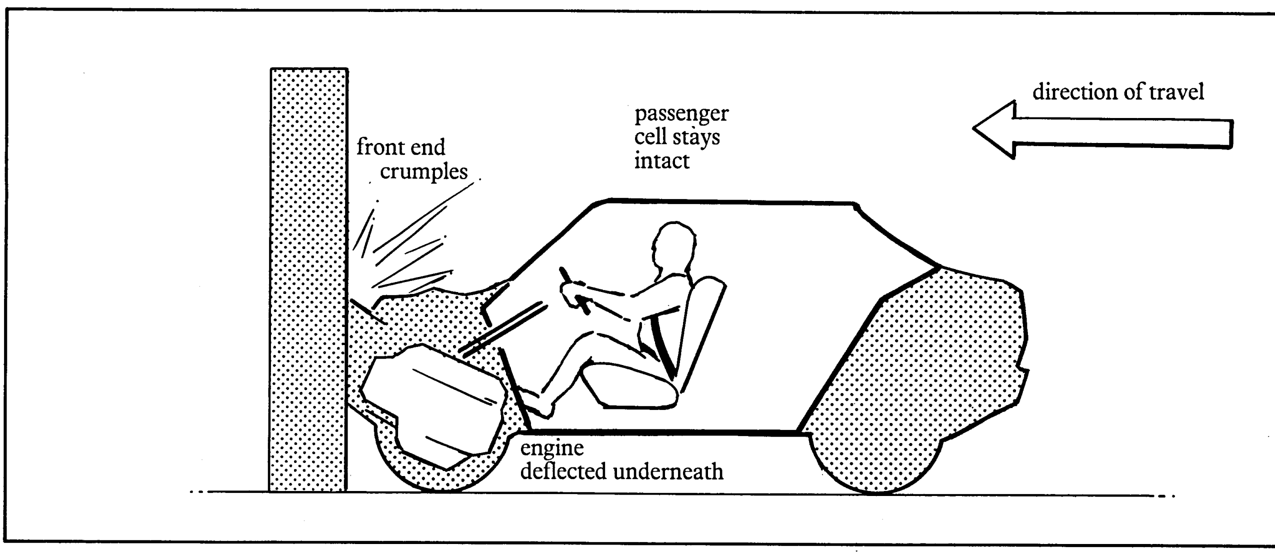

Figure 6 Modern cars have 'passenger cells' to protect passengers

A passenger in a car travelling at speed has a lot of kinetic energy. If the car crashes, it stops suddenly. But the passenger inside continues moving (Newton's First Law of Motion). Unless the passenger is thrown out of the car, they cannot move far. If they have no seat belt, they will hit some part of the car, and stop. All the passenger's kinetic energy will be converted to other forms of energy, and the passenger will probably be badly injured (Figure 7).

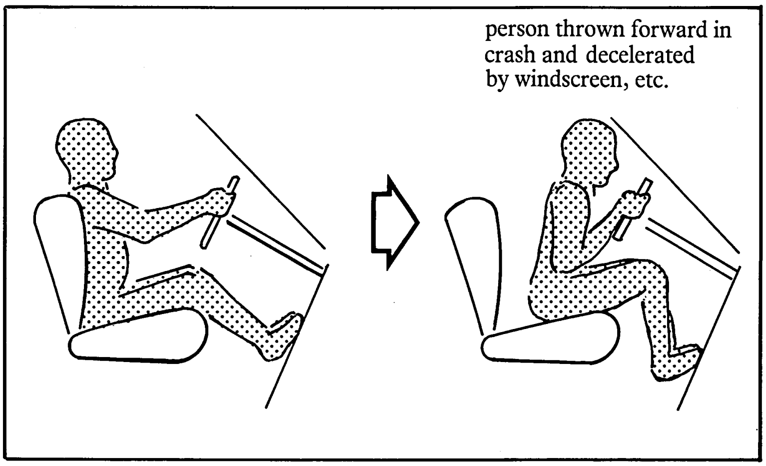

Figure 7 An accident without seat belt

Seat belts are designed to absorb the passenger's energy. When the car stops in the crash, the passenger continues moving forward, and the force on the seat belt causes the belt to stretch. This stretching absorbs energy. If the belts were made of a material that did not stretch, like steel, they would do a lot of damage. Seat belts are designed to stretch just enough to bring the passenger to a safe stop, but not enough to let the passenger hit the windscreen or other part of the car (Figure 8).

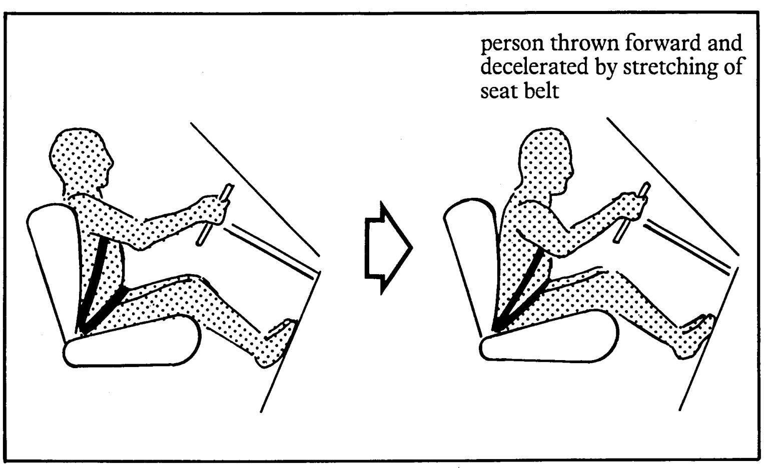

Figure 8 An accident with seat belt

The wearing of seat belts was made compulsory in Britain in 1983. Statistics suggest that this has saved over two hundred lives a year, and thousands of serious injuries.

Answer questions 16 to 22.

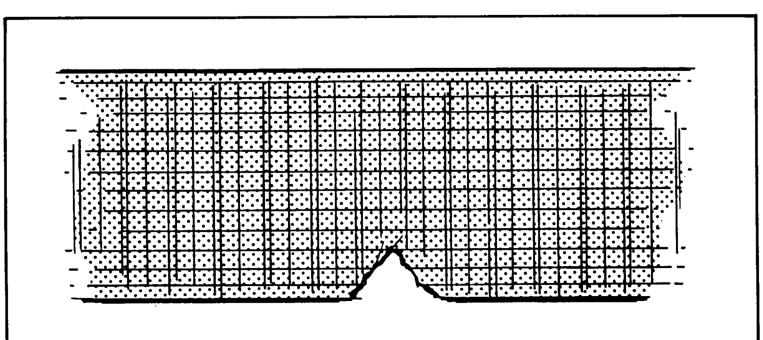

Figure 9 A torn seat belt. Why is it dangerous?

Questions

16 *Why is it important that seat belts are worn* tightly*?*

17 *Why do seat belts need to be wide?*

18 *Why do most seat belts pass across the chest* and *over the lap?*

19 *Figure 9 shows a seat belt that has become slightly torn at the edge. Why might this seat belt be dangerous in a crash?*

20 *Seat belts which have been 'used' in a collision should always be replaced by new ones. Why is this?*

21 *It is not compulsory for* rear *seat passengers to wear belts. Do you think it should be?*

22 *A man was heard to say: 'I don't see why I should wear a seat belt if I don't want to. It's my life.' Do you agree with his point of view?*

Making Fertilizers

Contents: Reading, questions and optional experimental work on the production and use of fertilizers.

Time: 2 periods or more, depending on amount of experimental work attempted.

Intended use: GCSE Chemistry and Integrated Science. Links with work on ammonia, fertilizers, acids, bases and salts. Best used after students have been introduced to ammonia and its use in making fertilizers.

Aims:

- To consolidate and revise prior work on ammonia and fertilizers
- To outline the industrial manufacture of fertilizers
- To show some of the factors involved in the siting and organization of a large chemical plant
- To develop awareness of some of the environmental problems associated with fertilizer use
- To provide opportunities to practise skills in reading, comprehension, the application of knowledge, experimental design and certain practical skills.

Requirements: Students' worksheets No. 505. For experimental work requirements, see below.

Notes on some of the questions

Q.2 Developing countries frequently have rapidly growing populations and often an associated food supply problem. Fertilizers provide an important means of increasing food supply, and it is obviously preferable if the fertilizer can be made at home rather than imported. However, supply of raw materials presents a problem; in particular fertilizer manufacture requires a substantial energy input, and this must frequently be imported as fossil fuel.

Q.10 Obviously, over-use of fertilizers must be avoided. It appears that the time of greatest fertilizer run-off is in autumn and winter, so it helps if fertilizer is not applied at these times. Normally, nitrogenous fertilizers are applied in the spring, when crops are growing fastest.

Qs 11 and 12 Students should appreciate that in a natural, balanced ecosystem the processes of decay and excretion will replace nutrients as fast as they are used by growing plants. Agriculture, however, disturbs this balance because crops are harvested and removed from the habitat. It is of course possible to grow crops 'organically', without the use of fertilizers, but this requires that all dead, decayed and excreted material is eventually returned to the land.

Further questions

For students who are familiar with the mole concept, quantitative questions could be set. For example:

A compound fertilizer contains ammonium nitrate, NH_4NO_3, ammonium dihydrogen phosphate, $NH_4H_2PO_4$, and potassium chloride, KC1, in the ratio 1 : 2 : 2 by mass.

(a) What is the mass of each compound in 100 g of fertilizer?

(b) Work out the percentages by mass of nitrogen, phosphorus and potassium in the fertilizer. (Relative atomic masses: N=14, H=1, O=16, P=31, Cl=35.5, K=39)

(Answers: (a) NH_4NO_3 20g; $NH_4H_2PO_4$ 40g; KCl 40g. (b) N 11.9%; P 10.8%; K 20.9%)

Making your own fertilizer

This is intended as a fairly open-ended exercise in experimental design. There is no 'right' answer, but the most successful approaches are likely to be based on some kind of titration, followed by evaporation.

Requirements for each group:

- ammonia solution (approximately 2M)
- sulphuric acid (approximately 1M)
- glass stirring rod
- conical flask (250cm^3)
- burette and stand
- measuring cylinder (50cm^3)
- universal indicator paper.

Testing your fertilizer

It is rewarding for students to test the fertilizer they have made, using cress seedlings.

Requirements for each group:

- three Petri dishes
- filter paper to fit the dishes
- cress seeds
- fertilizer made in previous experiment
- commercial fertilizer from a gardening shop (optional)
- distilled water
- measuring cylinder or graduated flask to measure to 1 dm^3
- three beakers (250cm^3)
- access to a balance.

Notes: 1 Students may need guidance and help with making the fertilizer solutions to the right strength.

2 It is most important that the dishes are checked and watered each day, as they dry out very quickly.

Further resources

There is a fuller account of fertilizer manufacture in the ICI publication *STEAM*, No. 3. Available from: ICI Education Publications, PO Box 96, 1 Hornchurch Close, Coventry, West Midlands, CV1 2QZ.

Acknowledgements Figures 1 and 2 supplied by ICI Agricultural Division; Figure 5 reproduced by permission from *STEAM*, No. 3.

MAKING FERTILIZERS

Figure 1 Applying fertilizer on farmland

Plants need certain elements in order to grow heathily. They can get most of these elements from the soil, but three elements are sometimes in short supply. These are nitrogen, N, phosphorus, P and potassium K. Table 1 shows the effect on plants of a shortage of each of these three elements.

Table 1 Effects of shortages of N, P and K

Element lacking	*Deficiency symptom*
Nitrogen, N	Harsh and fibrous leaves. Stunted growth.
Phosphorus, P	Grey and stunted leaves. Stunted growth.
Potassium, K	Premature death of leaves. Stunted growth.

These elements can be obtained from manure or compost, or from artificial fertilizers. In order to grow more food, modern farmers are using more and more artificial fertilizers. For example, 300 kg of nitrogen fertilizer on a hectare (10 000 m^2) of ground can double the yield of grass. The plants produced on soils that have had fertilizers used on them are not only larger, but also contain more protein and so have better food value.

Questions

1 *In 1900 the world's population was 1700 million. In 1984 it was 4800 million. In 1900 farmers used very little artificial fertilizer. In 1984, about 100 million tonnes of artificial fertilizers were used throughout the world.*

Explain why the use of artificial fertilizers has increased so much.

2 *Why is it particularly important for developing countries to develop their own fertilizer manufacturing industries?*

Types of fertilizers

There are several different types of fertilizer. The main ones made by ICI, one of Britain's largest manufacturers, are shown in Table 2. Look at the table then answer questions 3 and 4.

Table 2 Some of the main types of fertilizer

Name of fertilizer	*Elements it provides*	*What it contains*
NITRAM	N	Ammonium nitrate, NH_4NO_3
NITRO-CHALK	N	Ammonium nitrate absorbed in chalk, $NH_4NO_3/CaCO_3$
COMPOUND FERTILIZERS	N,P,K in varying amounts	Ammonium nitrate, ammonium dihydrogen phosphate, potassium chloride. $NH_4NO_3/NH_4H_2PO_4/KCl$ in varying amounts

Questions

Remember that the major elements needed for plant growth are nitrogen, N, phosphorus, P and potassium, K.

3 *Which type of fertilizer would you use on soil that was short of all three elements?*

4 *Which type of fertilizer would you use on soil that was short of nitrogen, and too acid?*

Figure 2 Some ICI fertilizers

How are fertilizers made?

Fertilizers are manufactured in enormous quantities. On a huge site at Billingham on Teesside, ICI Agricultural Division make a range of different fertilizers. The raw materials used for making the fertilizers are shown in Table 3.

Table 3 Raw materials for fertilizer manufacture

Raw material	*Where it comes from*	*Used to make*
nitrogen	the air	ammonia for all fertilizers
water	reservoirs in Teesdale	ammonia for all fertilizers
natural gas	North Sea	ammonia for all fertilizers
potassium chloride	mines at Boulby	compound fertilizers
phosphate rock	imported from overseas	compound fertilizers
sulphur	imported from overseas	sulphuric acid for compound fertilizers

Question

5 Billingham is particularly well situated for the manufacture of fertilizers. Use Table 3 and the map in Figure 3 to explain why.

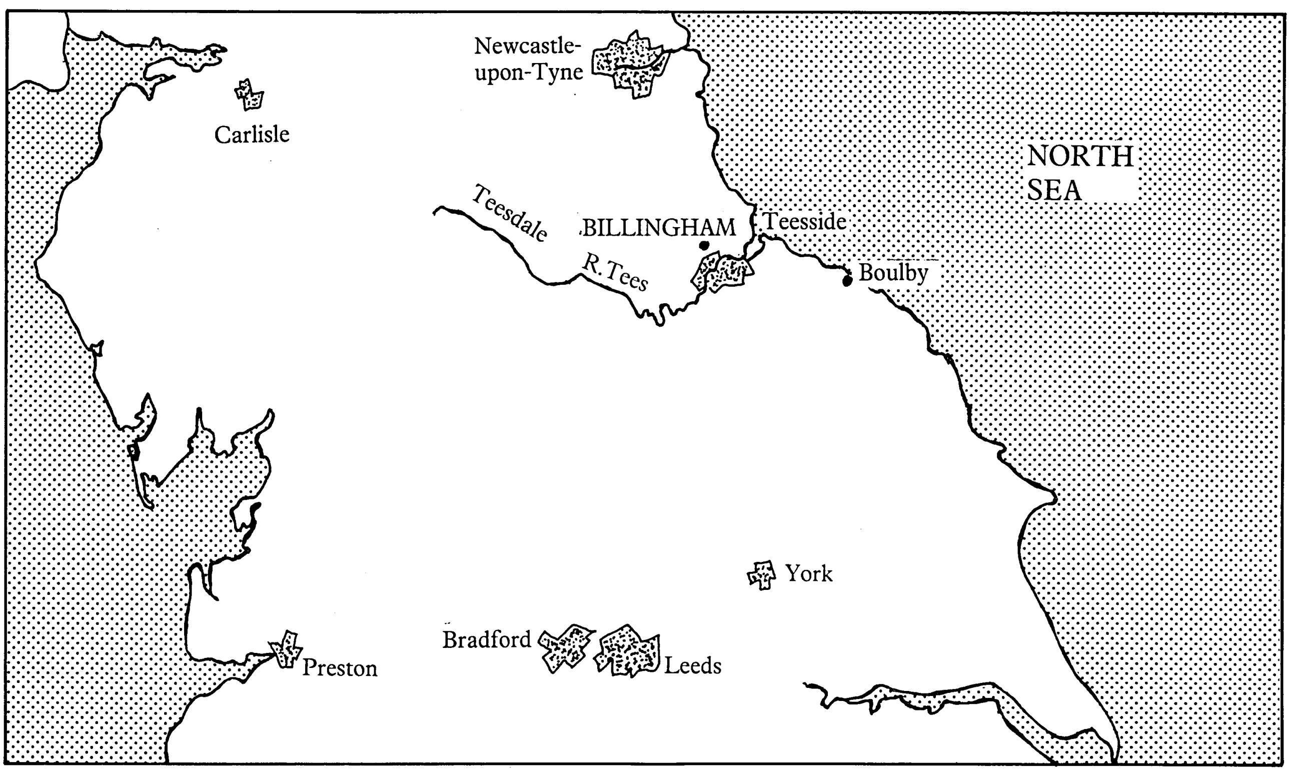

Figure 3 Map showing the location of Billingham

The fertilizer manufacturing site at Billingham is huge and complicated. Figure 4 on the next page shows the most important parts, though it is very simplified.

Look at figure 4, then answer questions 6 to 9.

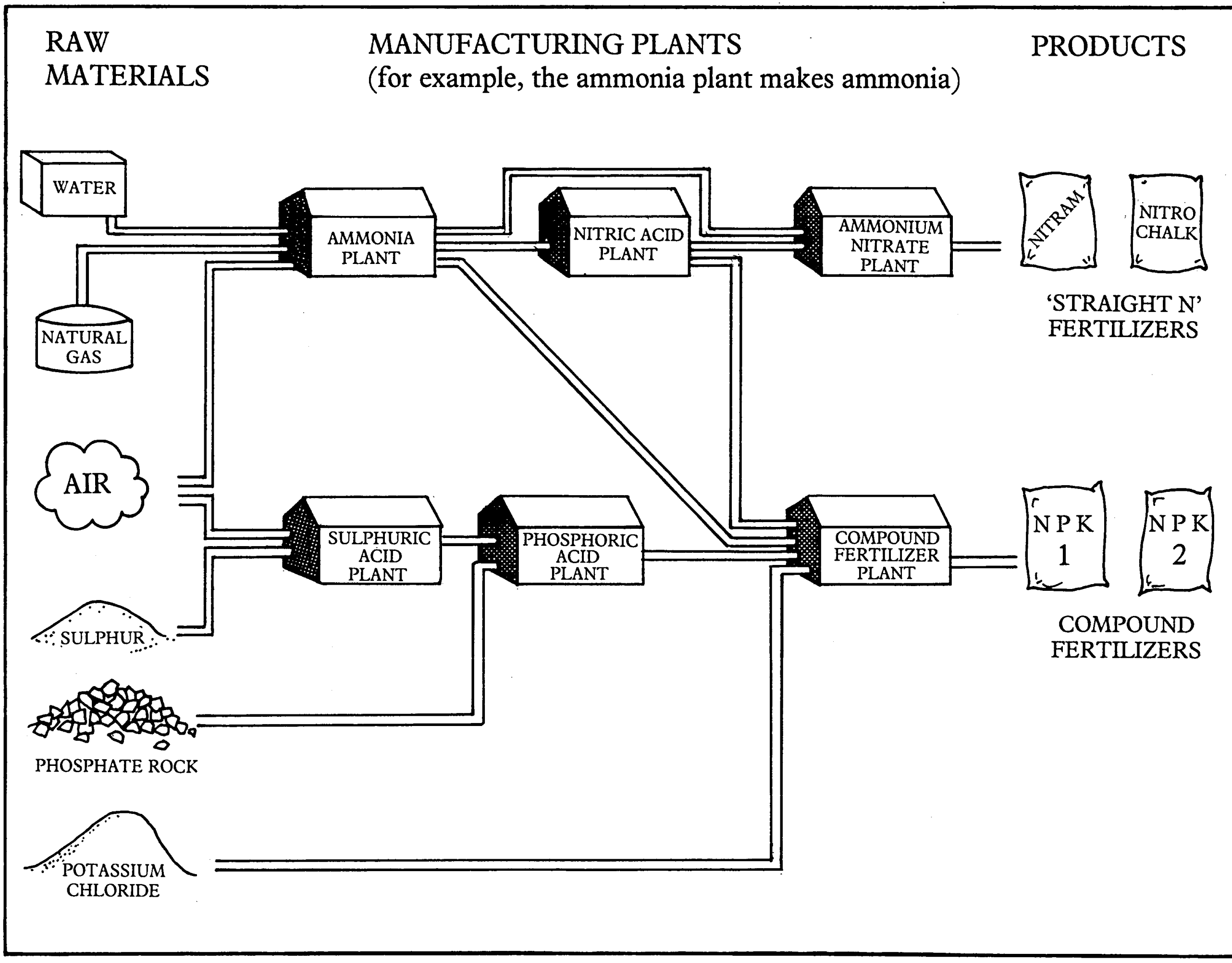

Figure 4 A simplified scheme of fertilizer manufacture

Questions

6 *Which plants use the ammonia from the ammonia plant?*

7 *What substances go into the compound fertilizer plant?*

8 *Why is it useful to have all the manufacturing plants on a single site?*

9 *What are the advantages and disadvantages for a community of having an industrial complex like Billingham nearby?*

Figure 5 Billingham complex

Problems with fertilizers

Fertilizers are important if we are to grow enough food for the world's huge and growing population. However, fertilizers can cause environmental problems.

Rain can wash fertilizers out of the soil and into streams, rivers and lakes. Once in the water, the fertilizers encourage bacteria and algae to grow rapidly. As they grow, they use up the oxygen in the water. In bad cases, the concentration of oxygen in the water can become very low. Without oxygen, many of the organisms die. The water becomes murky and smelly. This is called **eutrophication**.

Questions

10 *What could farmers do to try to avoid the environmental problems caused by fertilizers?*

11 *In a natural, undisturbed habitat such as a forest or moorland, plants grow perfectly well without fertilizers. Why, then, do plants grown for food crops often need fertilizers?*

12 *What changes would be necessary in modern farming in order to grow enough food* without *using fertilizers?*

Making your own fertilizer

You can make a nitrogenous fertilizer quite easily in the laboratory. The fertilizer is ammonium sulphate, and it is made from ammonia solution and dilute sulphuric acid.

$$\underset{\text{ammonia}}{2NH_{3(aq)}} + \underset{\text{sulphuric acid}}{H_2SO_{4(aq)}} \rightarrow \underset{\text{ammonium sulphate}}{(NH_4)_2SO_{4(aq)}} + 2H_2O_{(l)}$$

You will be provided with the following:

ammonia solution (approximately 2 M concentration)
sulphuric acid (approximately 1M)
glass stirring rod
conical flask (250cm^3)
burette and stand
50 cm^3 measuring cylinder
universal indicator paper.

You are to use these to make a pure, dry sample of ammonium sulphate crystals. Bear these points in mind:

- Ammonia solution and dilute sulphuric acid react together to make a solution of ammonium sulphate. The concentrations of the solutions are such that approximately equal volumes will react together.
- You should not use less than about 10 cm^3, or more than about 30 cm^3, of either of the two solutions.
- Ammonia is alkaline and sulphuric acid is acidic. Your ammonium sulphate fertilizer must be as near neutral as possible, otherwise it will damage the plants.
- Ammonium sulphate crystals decompose if heated too strongly.

Decide the method you will use, and discuss it with your teacher before going ahead with the experiment.

Testing your fertilizer

You can test the fertilizer you have made by trying its effect on cress seedlings. Grow the cress on filter paper watered with fertilizer solution. That way you can be pretty sure the only nutrients the cress is getting have come from your fertilizer.

You will need to grow at least two sets of cress — one for your fertilizer, and one for a control. You might also like to test a commercial fertilizer. You can buy these in small quantities from gardening shops.

What you do

1. Make a solution of your fertilizer in water. You must be sure to use the right concentration — only tiny amounts are needed. 0.5g of fertilizer dissolved in 1 dm^3 of water is about right.
2. Put a piece of filter paper in a clean glass dish.
3. Moisten the filter paper with your fertilizer solution so it is wet, but not swimming.
4. Sprinkle the filter paper **thinly** with cress seeds.
5. Set up a similar experiment as a control, using water instead of fertilizer solution. You could also set up a third experiment using commercial fertilizer. (Make sure you use the concentration recommended by the makers.)
6. Make sure the paper is always kept wet with fertilizer solution (or plain water for the control).
7. Compare the growth of the different sets of seedlings.

Materials for Life — new parts for old

Contents: Reading and questions concerning replacement surgery, with particular reference to hip replacement.

Time: 1 to 2 periods.

Intended use: GCSE Biology, Chemistry and Integrated Science. Links with work on the skeleton, joints, metals and materials.

Aims:

- To complement and revise work on the skeleton and joints
- To show the contribution that materials science has made to replacement surgery
- To develop awareness of the factors that need to be considered and decisions that need to be made, by doctor and patient, before undertaking major surgery
- To provide opportunities to practise skills in reading, comprehension and communication.

Requirements: Students' worksheets No. 506

Notes on some of the questions

Qs 1 and 2 If the operation is carried out before skeletal growth has stopped, a revision operation will be needed before long. Even when skeletal growth has finished, revision operations will be necessary because of loosening. By delaying the operation, the number of revisions can be reduced, and in any case technological advances may by then have reduced the loosening problem.

In addition, operating on the hip will cause growth to stop at the top of the femur. Kim's other leg will continue to grow and this would be expected to lead to a discrepancy in the length of the legs. This can cause a painful limp and may lead to arthritis in other joints such as the knees or the lower spine.

Young children tend to be very active physically and it would be difficult to persuade a child of Kim's age to refrain from taking part in normal activities once the new hip has been fitted. However, to do so could cause premature loosening of the prosthesis, leading to further surgery.

Q.5 Explain the nature of the disease underlying the problem in Kim's hip — that there is arthritis of the hip as a result of abnormal growth of the joint.

The condition is hereditary, so if Kim's parents have more children, they too may be affected. This should be explained to the parents. Kim's children too may be affected by the same condition in certain circumstances. If this is the case, the doctor would normally explain this to Kim's parents, but not yet to Kim.

The risks of the operation must be fully explained to Kim's parents, likewise the requirement for revision surgery in the future.

The need to abstain from vigorous exercise in the future must be explained to Kim and to Kim's parents.

The period of hospital confinement is often alarming and confusing for a child of Kim's age. The operation should be explained to the child and parents, followed by an explanation of what will happen following surgery in terms of when Kim will be allowed to stand, walk, sit, stop using a walking stick, etc.

Q.6

Advantages	**Disadvantages**
Relief from pain Ability to walk and be active	Discomfort of operation and hospital stay Risks of operation Need for revision operation in the future Possibility of failure of operation Need to abstain from vigorous exercise Possibility of later complications — loosening, infection, etc., and possibility of failure of subsequent operations.

Acknowledgements Figures 1 and 2 are reproduced by permission from *Science* by Graham Hill and John Holman (Nelson). Figure 6 supplied by Dr. G. W. Hastings.

MATERIALS FOR LIFE — new parts for old

This unit is in two parts.

Part 1 is about using materials to make replacement parts for the human body.

Part 2 has discussion points about an example of replacement surgery.

Part 1 What is replacement surgery?

Doctors use replacement surgery when old parts of the body wear out. They replace worn-out or diseased natural parts with artificial parts. Doctors call these artificial parts **prostheses**. You may have some replacement parts in your mouth. Teeth fillings and dentures are the commonest examples of artificial replacements. Figure 1 shows some other common examples.

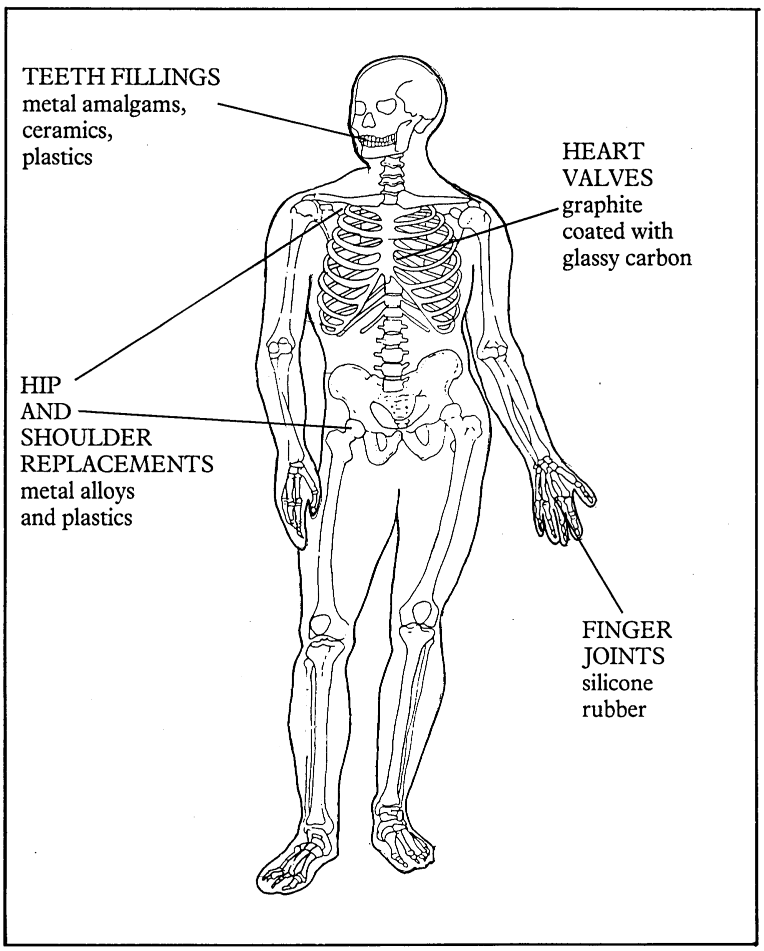

Figure 1 Some examples of artificial replacements

Artificial hips

Doctors have made dramatic progress in the last twenty years in replacing diseased or injured hip joints.

The hip is a ball-and-socket joint (Figure 2). An artificial hip uses an artificial ball, usually made of metal, and a socket, usually made of plastic. Choosing the right materials is tricky, because they must be:

- Corrosion-resistant — otherwise they will be corroded by body fluids.
- Hard-wearing, so they do not wear out.
- Low-friction, so the hip moves smoothly.

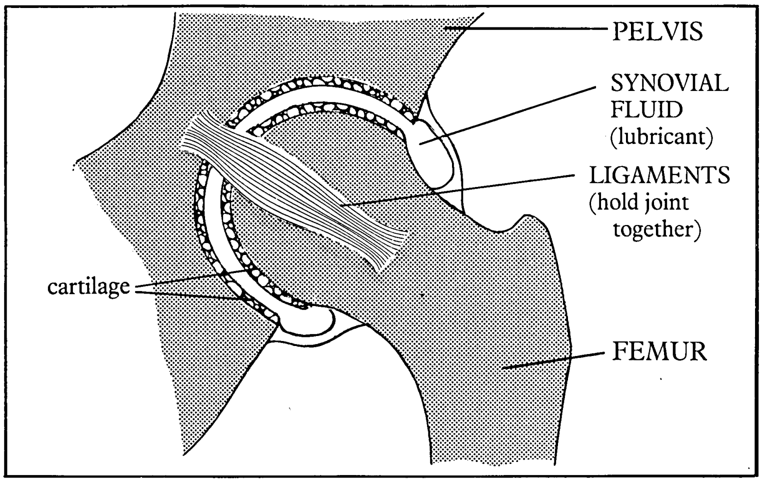

Figure 2 The hip joint

Figure 3 shows how an artificial hip is fitted. A stainless steel ball is fixed into the hollow stem of the femur (thigh bone). This fits into a cup made from a special grade of polythene (ultra high molecular mass polythene, relative molecular mass approximately 4 million). The two parts (ball and cup) of the prosthesis are fixed into the bones with cold-setting acrylic cement.

To reduce the chance of breakage from metal fatigue, different metal alloys are being introduced. One of the most important changes has been the replacement of the metal ball by one made from ceramic. High purity dense aluminium oxide is used, which is nearly as hard as diamond. It is chemically unreactive and has low-friction. This cuts down wear of the polythene cup.

Loosening is a major problem with replacement surgery. In active people, artificial hips may have to be replaced every seven years or so because they have become loose. One way round it is to put bumps on the surface of the prosthesis to help it 'key' to the bone (Figure 4a). Another possibility is to make the artificial part out of a porous material. The living tissue grows into the pores (Figure 4b).

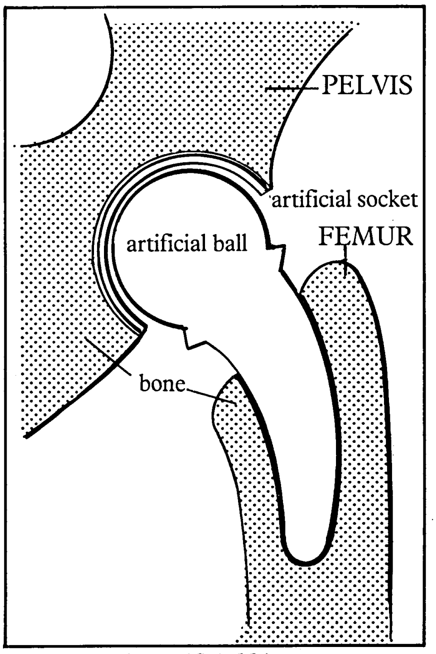

Figure 3 An artificial hip

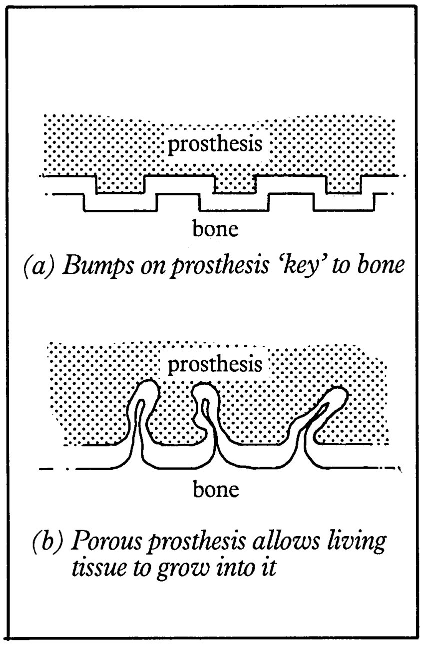

Figure 4

What about the future?

Every year many thousands of people have successful hip replacements. They are freed from pain and can move around much more easily. This reduces burdens on relatives and doctors. The change after the operation is generally dramatic. Most important of all, patients are freed from pain.

Still, there is plenty of room for improvements in replacement surgery.

Doctors are trying out new materials all the time. Titanium is a promising metal. Carbon-fibre reinforced plastic is beginning to be used. This has tough carbon fibres embedded in a matrix of plastic resin (Figure 5). The best hope for the future is to produce materials which are better tolerated by the body, and less 'foreign'. Chemists, materials scientists, biologists and engineers are working on the problem as well as doctors. Their future discoveries will help make life easier for people with worn-out parts in their bodies.

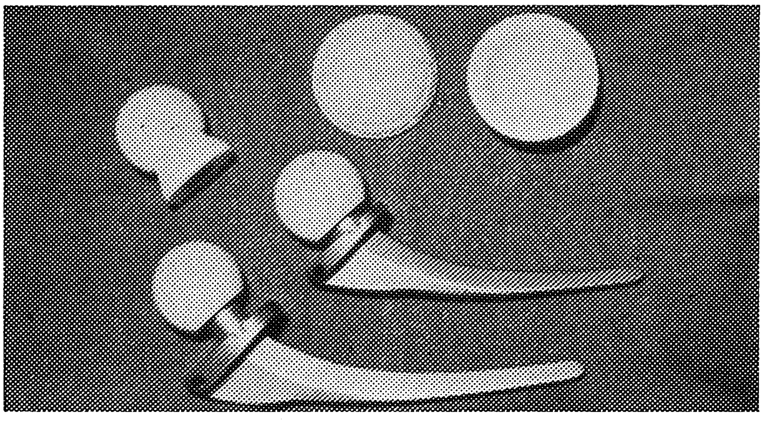

Figure 6 Artificial hips, showing the metal ball and stem, and the white plastic cup.

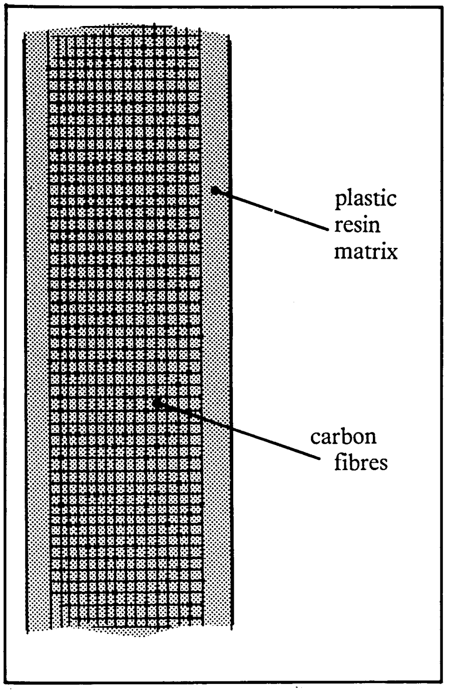

Figure 5 Carbon fibre reinforced plastic

Part 2 Kim — a case for replacement surgery

Kim's case is imaginary, but it is based on real life. Read through the description of the case, then discuss the questions.

The case

Kim was a very active 12-year-old when the hip problem was discovered. Kim has inherited a condition which causes the end of the thigh to be shaped abnormally. This means the ball does not move smoothly in the socket. It is a painful condition, and will probably get worse. Eventually Kim may have to give up sport, and may be confined to a wheelchair. However, it is unlikely that the disease will spread to other joints.

Doctors decided that a hip replacement was necessary but do not want to operate yet. For one thing, they do not want to operate until Kim has stopped growing. For another, the doctors know that at present artificial hips gradually loosen and have to be replaced. By delaying the operation a few years, doctors can reduce the total number of operations Kim will need. Besides, progress in the next few years will probably bring big improvements which may well solve the loosening problem.

Every surgical operation under anaesthetic has a small risk of going wrong. The risk in Kim's case would be no worse than normal. After the operation Kim would be free from hip pain. There might be some problems with mobility, at least at first.

After the operation Kim will need to be careful about taking part in sports. Vigorous activity could loosen the hip, which could lead to another operation. Kim will always need to be aware that the hip will never work quite as well as a natural one.

Questions to discuss

1 *Why do doctors not want to operate until Kim has stopped growing?*

2 *What other advantages are there in delaying the operation?*

3 *What are the* disadvantages *of delaying the operation?*

4 *When Kim comes to have the operation, what materials might doctors use for (a) the ball and (b) the cup of the artificial hip?*

5 *Suppose you are the doctor responsible for Kim's case. You have to explain to Kim and Kim's parents what is wrong with the hip, what you are going to do, and why. What will you say? Is there anything you would choose* not *to tell them? Is there any information missing here which you think you need?*

6 *Before agreeing to have the operation, what advantages and disadvantages will Kim need to weigh up? What further information might Kim want to ask the doctors for?*