Artificial Limbs

Contents: Reading, questions and discussion on artificial legs and arms.

Time: 1 to 2 periods, depending on amount of discussion.

Intended use: GCSE Biology, Human Biology and Integrated Science. Links with work on movement, muscles and nerves.

Aims:

- To complement work on muscles, movement and nerves
- To develop awareness of the problems encountered by people with missing limbs
- To show some of the ways technology can be used to provide effective artificial limbs
- To provide opportunities to practise skills in reading, comprehension and communication.

Requirements: Students' worksheets No. 707

Notes on some of the questions

Q.1 The basic essentials for an artificial leg are a socket for attachment and a strong, rigid shank. The old fashioned wooden leg was little more than this.

An ideal artificial leg must allow for flexing of the knee and ankle when walking, though the knee must not flex too freely or the leg may collapse under weight. The leg needs to be light enough to move easily: modern legs use lightweight materials such as carbon-fibre reinforced plastic.

A very important aspect is the appearance of the leg. A crucial function of artificial limbs is to restore the person's 'body image', and to this end the leg needs to be as natural looking as possible.

Q.3 Obviously the dimensions of the leg need to be tailored to fit the individual person. This fitting is done by highly trained prosthetists. It is particularly important to tailor the socket to fit the stump closely, otherwise looseness and soreness will result.

Q.6 To move each finger separately, under voluntary control, it would be necessary for sensors to collect information from the individual nerves controlling each finger. At present this degree of selectivity is impossible.

Notes on the discussion points

The psychological problems of losing a limb are often as severe as the physical problems. Patients often need a great deal of help in adjusting to their new life-style and altered body image. Generally, people adapt better to losing an arm than losing a leg.

Artificial limbs are the subject of considerable research both in this country and overseas. A promising area for development seems to be the field of sensing and feedback. Artificial hands are being developed which incorporate touch sensors. These can record the position of the fingers and feed this information to a microprocessor which in turn controls the movement of the motor.

Another area of research is the energy source which powers the arm. Batteries have severe limitations of lifetime and output. Possible developments include pneumatically powered limbs, incorporating a self-powered pump for compressing air.

The final discussion point is intended to encourage students to think about their own attitudes to handicap, and their reactions when they meet handicapped people.

Further activities

Artificial limbs are supplied by the Limbfitting Service of the Department of Health. There are thirty Limbfitting Centres around the country, and it might be possible to arrange a visit or visiting speaker by contacting a local centre.

Acknowledgements Figures 1 and 7 supplied by the Department of Health and Social Security Limbfitting Centre, Roehampton; Figure 3 supplied by *The Hemel Hempstead Gazette*.

ARTIFICIAL LIMBS

Artificial limbs may make you think of peg-legged pirates, or Captain Hook with his hook hand. But today's artificial limbs are rather different. Often you don't notice them at all, and they can do many of the jobs of an ordinary limb.

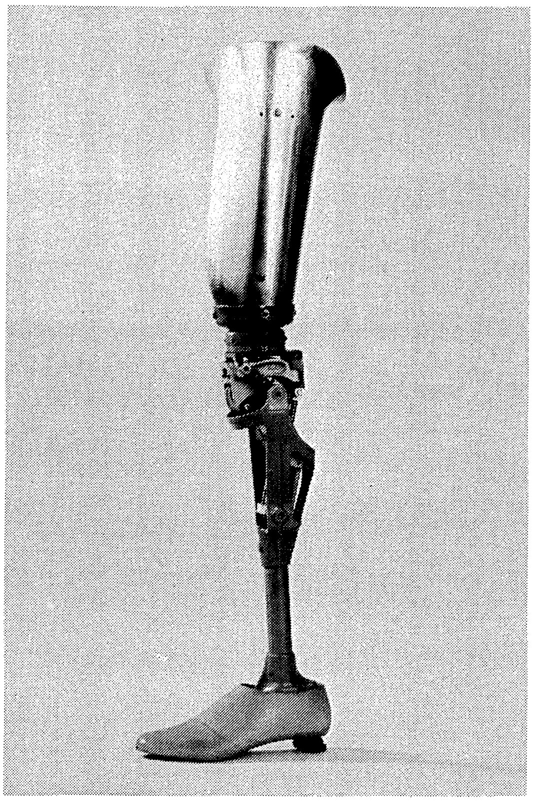

Figure 1 An artificial leg without its outer cover, showing the basic structure

Walk around and think about the jobs your leg has to do. Now try walking with your leg completely stiff. Don't bend the ankle or knee at all. Now think about the essential properties an artificial leg would need.

Answer question 1.

Every year about 5000 people are fitted with artificial limbs for the first time. People need artificial arms or legs for one of two reasons:

- They were born with a limb, or part of a limb, missing.
- They have had a limb removed (amputated).

The most frequent reason for having a limb amputated is disease. A common disease in old people is **arteriosclerosis**. Smoking is a major cause of this disease. In arteriosclerosis the blood vessels get clogged up. The limbs, especially the legs, do not get enough blood supply. If the leg gets infected, there may not be enough blood supply to fight the infection. A serious infection called **gangrene** may develop. The leg may have to be amputated to stop the gangrene spreading.

About 85 per cent of all amputations are done on old people with arteriosclerosis. The remaining 15 per cent are mostly needed after accidents, particularly road accidents. A very seriously damaged limb may have to be amputated because it cannot be repaired.

Question

1 What essential properties would an artificial leg need to have?

Helen — a case study of artificial legs

Helen had just started a degree course at London University in October 1984 when she became ill. She suddenly developed a severe rash on her body, and a high temperature. She was admitted to hospital suffering from a rare disease called *meningococcal septicaemia.*

Helen was extremely ill and needed an artificial breathing machine. Due to complications of the illness, the blood vessels to both her legs and to the tips of her fingers became blocked. She had to have both legs amputated below the knee. The tips of three of her fingers also had to be amputated.

Helen was fitted with her first pair of artificial legs in February 1985. She stayed in hospital until April 1985, learning to walk. She left hospital in May 1985 but continued to have physiotherapy three times a week.

Helen's physiotherapy continued until October 1985. During this time her walking improved so she could walk with two sticks. She went on several outings with the physiotherapist, to help her learn to cope with shopping, escalators and so on. She also worked hard on her hands, because they had become stiff after the operation. She learnt to type, and learnt how to put on her artificial legs.

In October 1985, almost exactly a year after her illness started, Helen returned to university to start again on her degree course.

Figure 2 Helen in 1986 at the University of London

Nigel — a case study of an artificial arm

Nigel was born with his right arm missing below the elbow.

He was fitted with his first artificial arm at 8 months old. This was just a 'cosmetic' arm for the sake of appearance. When he was 18 months old he had his first 'working' arm. This was a split hook which he could open and close.

Since then Nigel has led a normal life and has attended an ordinary school without any problems. He is very active, enjoys sport and has many friends. He plays football for the school team. When he was 13 he was voted 'Athlete of the Year' by his school.

Nigel has two types of artificial arm:

1 A body-powered arm with various attachments. The attachments include a split hook, a canoeing hook, and various gripping appliances which Nigel uses when he is doing CDT at school.

2 A myoelectric, battery-powered arm.

Nigel finds his split hook useful for most things he needs to do. As Nigel grows, he needs to be fitted with new, larger arms at regular intervals.

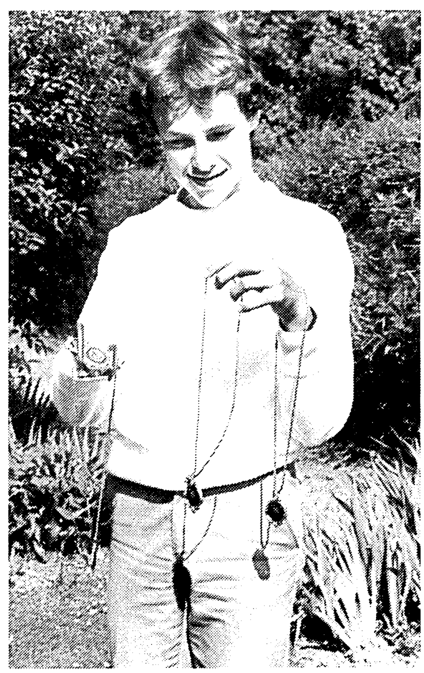

Figure 3 Nigel wearing his split hook hand, holding medals he won at the Stoke Mandeville Games

How do artificial limbs work?

Artificial legs

Think back to when you were answering question 1. You probably realized the problems of walking with a stiff leg. An ideal artificial leg needs to bend at the knee and ankle, like a real leg. But this can cause problems. If it is *too* easy to bend, the leg may collapse under the person's weight.

The answer is to make a leg that can bend, but with a knee that locks when weight is on it. The knee must be able to unlock and bend easily when the person sits down. Figure 4 shows an artificial leg for a person who has had an amputation above the knee.

After amputation a stump is left, and this fits into a socket in the artificial leg. When the person walks, they swing the artificial leg by using their muscles to move the stump. If both legs are artificial, they may need sticks to help them walk.

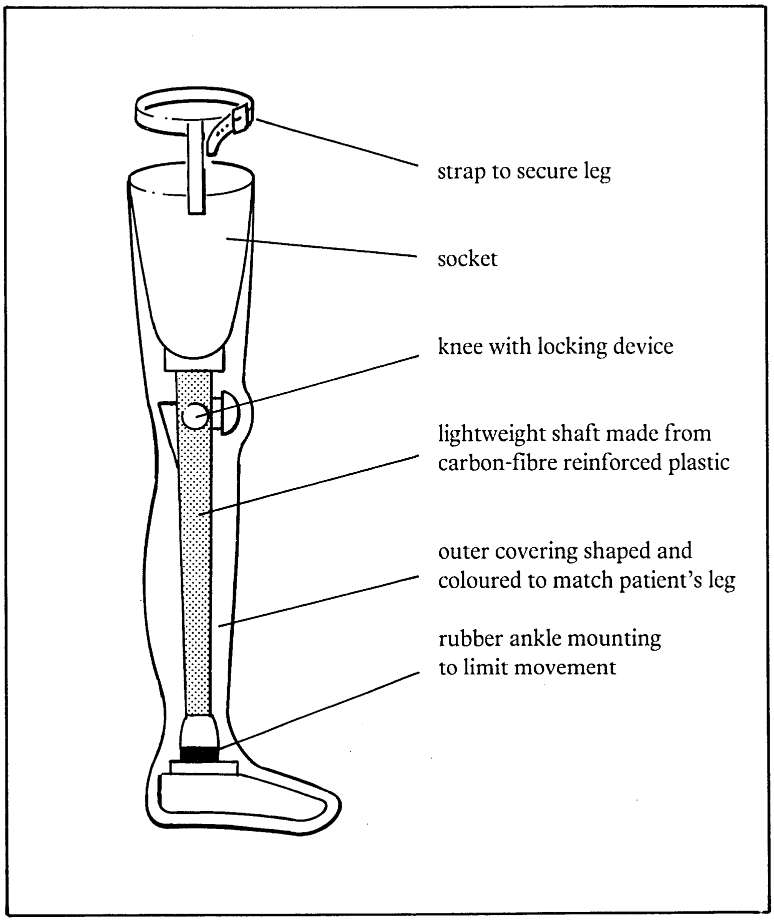

Figure 4 An artificial leg for a person with an above-knee amputation

Questions

2 *Suppose an artificial leg is designed for a* below-knee *amputation. In what ways would it be different from the one in Figure 4?*

3 *Which parts of the leg in Figure 4 would have to be tailored to suit each different patient? Which parts would be standard for every patient?*

Artificial arms

If an artificial arm is to be useful, it must have a hand that can manipulate things. This hand may be powered by the patient's own body, or by electricity.

Body-powered hands

These are usually operated by a strap attached to the shoulder. Figure 5 illustrates the arrangement.

Split hooks are particularly useful, but many other attachments are possible. People can get attachments to suit their particular work or interests. There are special attachments for typing, gripping, hammering and so on.

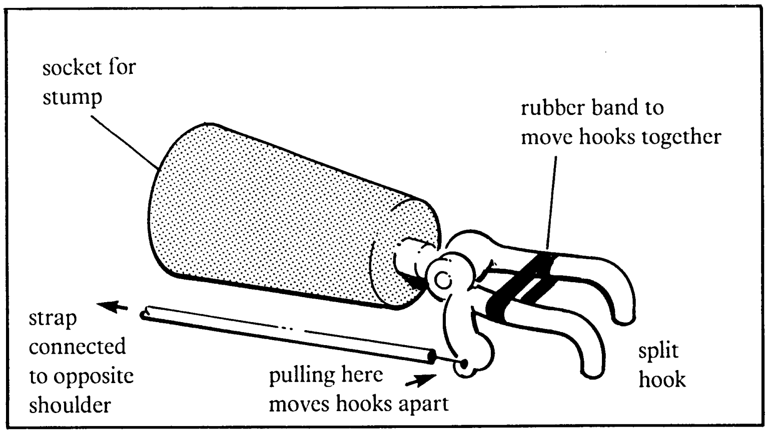

Figure 5 A body-powered hand

The myoelectric hand

When you want to move your own hand, your brain tells the muscles what to do. Messages are sent from the brain to the muscles, as tiny electrical impulses along nerves. The electrical impulses make the muscles contract.

The myoelectric hand uses these electrical impulses to control a battery-powered hand. It is sometimes called a 'bionic hand'. Figure 6 shows the arrangement.

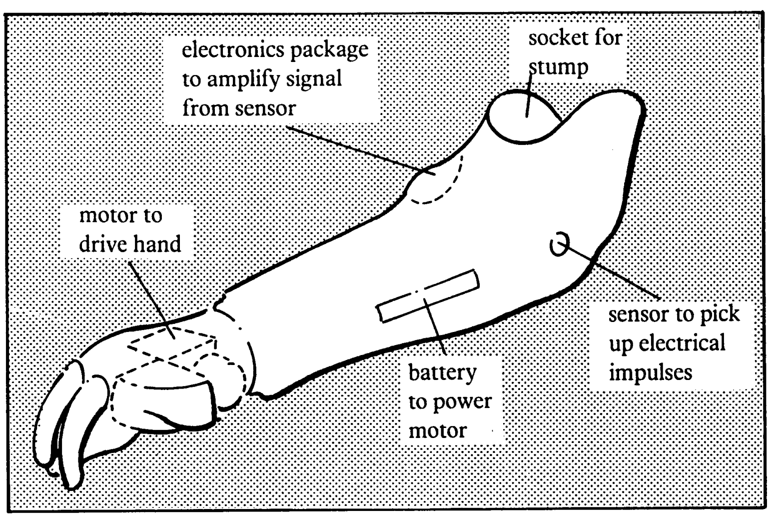

Figure 6 A myoelectric hand

The sensor touches the skin of the stump. It is positioned as near as possible to the muscles which remain in the stump. When the brain sends electrical impulses down the nerves to these muscles, the sensor detects the tiny electric currents. The current is amplified to make it large enough to work a switch. The switch turns on a motor which moves the artificial thumb and fingers. All the person has to do is think and the hand moves.

There are usually two sensors. One can be used to turn the motor on, the other to turn it off. The motor is driven by a small rechargeable battery.

The hand has a flexible plastic covering, coloured to look like the person's own skin. Its appearance is very like a natural hand.

Myoelectric hands can be fitted to very young children. Most children learn how to use them much quicker than adults.

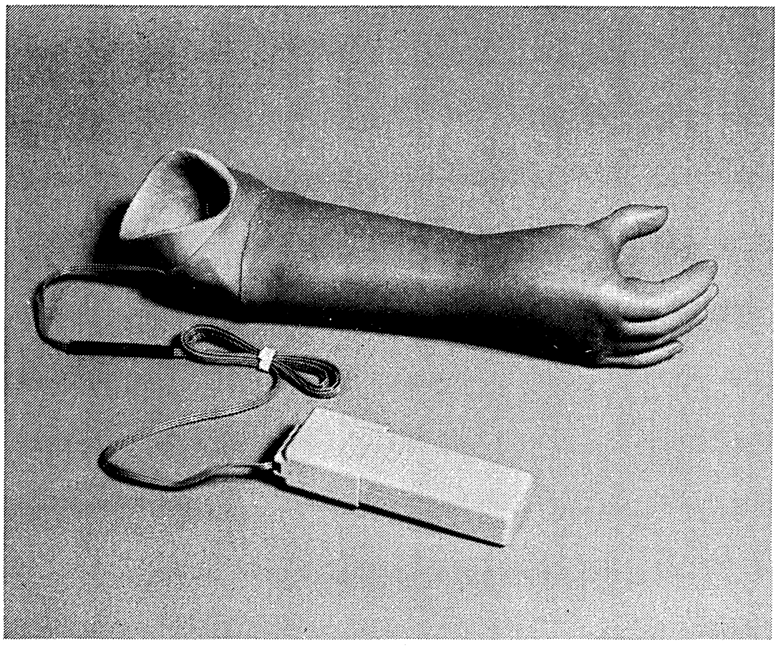

Figure 7 A myoelectric hand

Questions

4 *What advantages does a myoelectric hand have over a body-powered hand? Does it have any disadvantages?*

5 *It is not practical to make electric powered legs. Why not?*

6 *Myoelectric hands can only do a single movement — a grip between thumb and fingers. Why is it not possible to move each finger separately?*

Further points to discuss

- Describe what you think you would feel if you were told you had to have a limb amputated.
- Think of some particular problems about managing with artificial legs. Suppose you need to get out of bed in the middle of the night? What about escalators? Would you be able to manage putting your legs on without help?
- Which do you think it would be easier to adjust to — losing an arm or losing a leg?
- Sometimes people have a limb cut clean off in an accident. When this happens it may be possible for a surgeon to sew the limb back on. What difficulties can you see about doing this operation successfully?
- What major progress do you think there could be in the technology of artificial hands in the future?
- Artificial limbs do not have **senses** like real limbs. What senses would it be useful to build into an artificial hand? Would it be possible to do this? How could it be done?
- How could modern technology help (a) blind people; (b) people who are paralysed?
- A person with artificial legs has said: 'The worst problem that handicapped people have is other people'. What did she mean?

Appropriate Pumps

Contents: Information, questions and discussion on appropriate technology as applied to water pumps for developing countries.

Time: 2 periods.

Intended use: GCSE Physics and Integrated Science. Links with work on pressure and pumps.

Aims:

- To complement work on pressure and pumps
- To develop awareness of the need for clean water supplies, and the problems involved in securing them in developing countries
- To introduce the concept of appropriate technology and to show its importance
- To provide opportunities to practise communication skills and problem-solving skills.

Requirements: Students' worksheets No. 708

The main task in this unit involves students attempting to deduce how the three pumps work. This task, and indeed all the questions, are best tackled by students working in groups of two or three. This will encourage students to discuss the workings of the pumps, and some of the wider issues, with one another. Explanations of the workings of the pumps are available (pages 6—7 of the students' sheets), but it is for the teacher to decide whether to duplicate and issue these, or whether to bring out the explanations through class discussion. In any case, students should be given ample opportunity to tackle the explanations before they are given the 'answers'.

Notes on some of the questions

Q.1 The translation of the poster is:

The fine well is being wrongly used:
(a) The surroundings of the well are dirty
(b) Cattle can come and drink at the well
(c) The women wash clothes near the well
(d) Nothing is done to keep out the cattle.

Avoid giving the impression that this is the condition of *all* wells: the poster is of course highlighting the common causes of contamination by reference to a single well.

Q.2 Serious water-borne diseases include typhoid, cholera, dysentry and diarrhoea. It has been estimated that in developing countries some seven million children under the age of 5 die each year from diarrhoea resulting from drinking polluted water.

Q.4 The rope pump can in principle raise water from any depth. In practice there is always some leakage between the knots and the tube. The greater the depth from which the water is raised, the higher the pressure on the lowest knots, and the faster the leakage.

Q.5 An important feature of the hose and bucket pump is the width of the hose relative to the capacity of the bucket. The hose needs to be fairly narrow so that the volume of water needed to fill the hose itself is small compared to the capacity of the bucket.

Q.6 The displacement pump can in principle raise water to any height. In practice, the height to which it can be raised is limited by the leakiness of the valves: the higher the column of water in the rising main, the greater the pressure on the valves, and the more they leak.

Q.8 (c) The machine would use expensive electricity, would require imported plastic (or home-produced plastic made from imported oil) and would create unemployment. Hand-made leather sandals might be more appropriate.

However, students might like to discuss the broader aspects of development. For example, it is often argued that without advanced technology, developing countries will stay underdeveloped and never break out of the cycle of poverty.

Q.9 Examples that could be discussed might include cars versus bicycles and public transport, garden machinery (for example, lawnmowers) microwave cookers and dishwashers.

Further resource material

The PLON physics project from The Netherlands includes a unit, *Water for Tanzania*, on which much of this unit is based. *Water for Tanzania* includes full background information on the pumps, practical work and geographical details on Tanzania and the water problem. It is available from: PLON, Physics Education Department, State University of Utrecht, PO Box 80-008, 3508 TA Utrecht, The Netherlands.

Earthscan publish a number of books relating to water supply in developing countries. Details from: Earthscan, 3 Endsleigh Street, London WC1H ODD.

Acknowledgements Figures 1 and 4 supplied by UNICEF; Figure 9 supplied by World Health Organisation; Figures 2, 5, 6, 7, 8, 10, 11 and 12 reproduced by permission from *Water for Tanzania*, PLON, The Netherlands.

APPROPRIATE PUMPS

When you turn on the tap, you assume the water that comes out will be clean and safe to drink. But hundreds of millions of people in developing countries have no taps — let alone clean water to come out. In many parts of Africa, Asia and South America, people have to walk miles to get water, and even then it may be dirty and carry disease. In developing countries, 30 000 people die *every day* because of contaminated water supplies.

The United Nations has declared 1981-1990 to be International Drinking Water and Sanitation Decade. The aim is to provide safe, clean water supplies and sanitation for everyone by the year 1990. It is estimated the programme will cost £44 million for *every day* of the decade.

Many developing countries have hot climates. This often makes water difficult to find. In many places, the only source of drinking water is a pool. Often the pool is used for washing as well as drawing water. The water can easily get infected and can be a major source of disease.

One way round the problem is to draw water from below the ground. This **groundwater** is usually clean and uncontaminated. But to draw groundwater needs a pump. In this unit we will be trying to decide the most suitable pumps for the job.

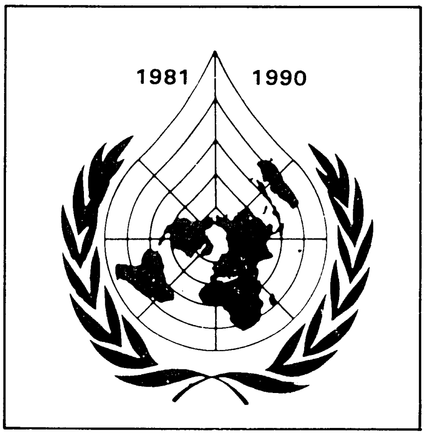

Figure 1 The symbol of the International Drinking Water and Sanitation Decade

Figure 2

Questions

1. *The poster in Figure 2 comes from Tanzania. It warns people about the danger of polluting drinking water. What do you think the words might say?*
2. *Name two or more diseases that are spread through drinking water.*
3. *Water-carried diseases were common in Britain as little as fifty years ago. Why are they very rare today?*

What makes an appropriate water pump?

Pumps are used everywhere. They are used for pumping water supplies, pumping sewage, pumping oil and pumping air. Your house may have a pump like the one in Figure 3 to send water round the central heating. If you have a car it will have a pump to send petrol from the tank to the engine.

We do not often notice pumps in Britain, because they are usually driven by electricity and quietly switch themselves on and off. They are usually made from high quality materials and rarely break down.

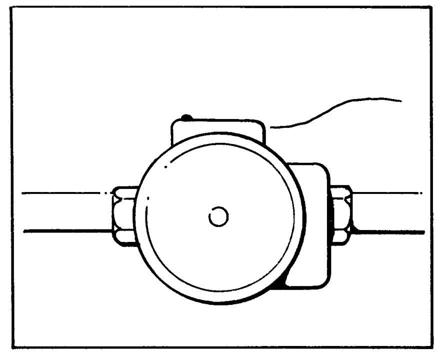

Figure 3 A central heating pump

A water pump for a developing country needs to be rather different. Electricity is often not available. Petrol and diesel fuel are expensive, so the pump must usually be operated by hand. The pump must be cheap. It needs to be easy to maintain and repair by local people. This means it must be simple, and made from local materials. It is no use having to send for parts from abroad when the pump breaks down.

This 'checklist' gives the main features needed in a water pump for a typical African village:

- Does not need electricity or fuel
- Needs little maintenance
- Cheap
- Made from local materials
- Must raise water from a well at least 5m deep
- Must be able to pump enough water for all the members of the village
- Must be built so the well water cannot become contaminated.

Figure 4 A village handpump in Nigeria

Three pumps

We will now look at three different kinds of pumps that could be appropriate for a developing country. In each case you will be asked to try to explain how the pump works. You will find it helpful to work with another student or students to discuss how the pumps work.

1 The rope pump

Look at Figures 5 and 6, then answer question 4.

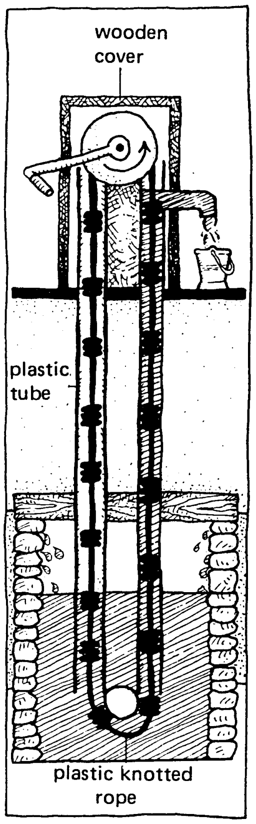

Figure 5 The rope pump

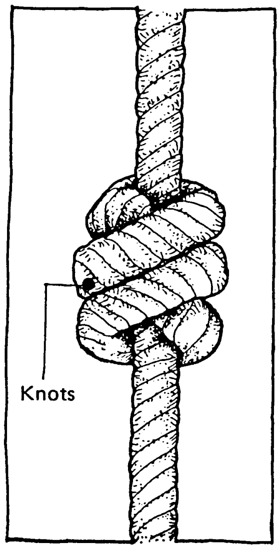

Figure 6 The special knot for the rope pump

> *Question*
>
> *4 Write a few words beginning 'When the handle is turned . . .', to describe how you think the pump lifts water.*

2 The hose and bucket pump

Look at Figures 7a and 7b, then answer question 5.

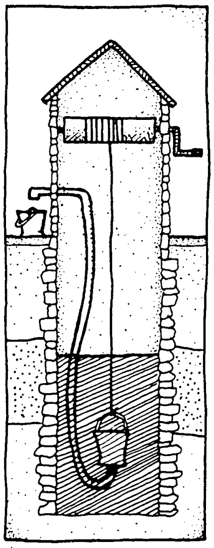

Figure 7a

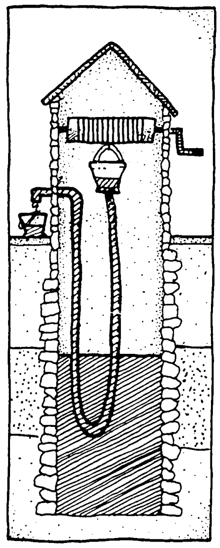

Figure 7b

> *Question*
>
> *5 Write a few words, beginning 'When the handle is turned to raise the bucket . . .', to describe how you think the pump lifts water.*

3 The displacement pump

Look at Figure 8, then answer question 6.

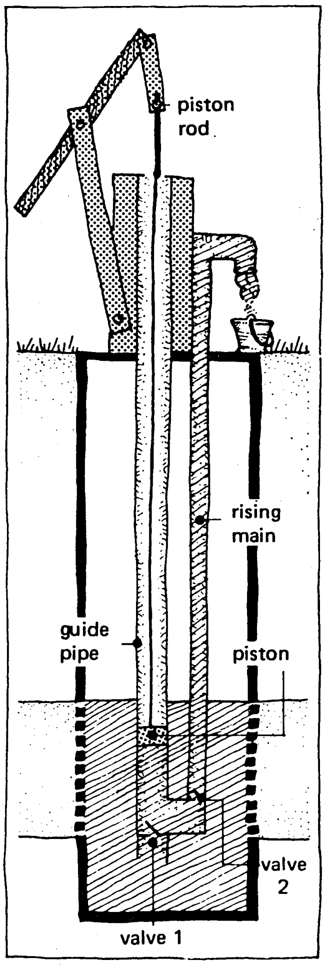

Figure 8

> *Question*
>
> 6 *Write a few words, beginning 'When the handle is pushed down . . .', to explain how you think the pump works.*

Appropriate technology

The pumps we have been looking at are examples of **appropriate technology**. In a village in a developing country, there is often no mains electricity. So electric pumps would not be appropriate technology in this case. A much simpler technology would be for each person to lower their own bucket into the well on the end of a rope. But this would not be appropriate technology either. It would be slow, and it might help spread disease from one family to another. Appropriate technology fits people's needs *and* what they have available to make the technology work.

Advanced technology like computers and tractors is often not appropriate for developing countries. Some of the difficulties with advanced technology machines are:

- They are often expensive, and have to be imported from developed countries like Britain, USA and Japan.
- They usually require energy in the form of electricity or oil. Energy is often expensive or difficult to obtain in developing countries.

- They need skilled technicians to maintain and repair them. A supply of spare parts is also needed, and these usually have to be imported.
- They replace human workers and create unemployment, which is often already very high.

Appropriate technology uses *local* materials, *local* energy sources and *local* workers to meet the needs of the *local* people.

More questions for discussion

7 *Choose* one *of the three pumps which you think would be particularly appropriate for a village in a developing African country. Say* why *you think it would be appropriate. (Look back at the checklist on page 2.)*

8 *For each of the following, explain why the technology given would* not *be appropriate. Suggest a more appropriate technology in each case.*

(a) A diesel tractor for ploughing fields around a remote African village

(b) A microwave cooker for a household in a village in Peru, South America

(c) A machine to make plastic-soled sandals for an Indian footwear manufacturer.

9 *Is all the technology used by you and your family appropriate? Could you manage with less advanced technology in some cases? Give some examples.*

10 *Advanced technology needs energy supplies, spare parts and qualified engineers. Why are these things easier to provide in Britain than in developing countries?*

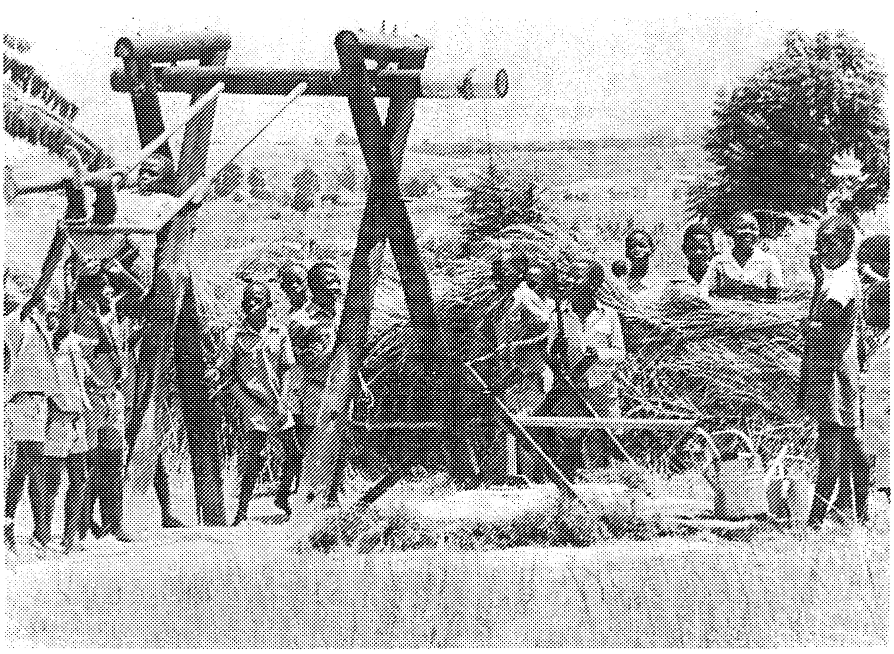

Figure 9 This children's swing in Zimbabwe also operates a water pump.

How the pumps work

1 The rope pump (Figure 10)

When the handle is turned, the knots raise the water in the right-hand tube. When the water reaches the outlet it flows out. Some water flows back because it leaks past the knots. This can be improved by fitting rubber discs (cut from old tyres) as seals in front of the knots.

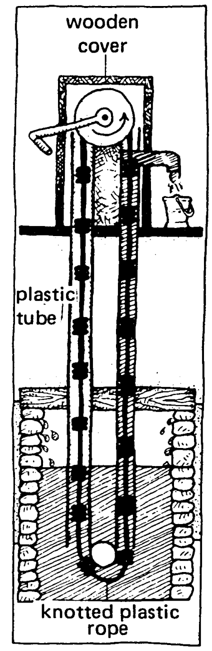

Figure 10

2 The hose and bucket pump (Figure 11)

When the bucket is under the water, it will fill completely with water. When the handle is turned to raise the bucket, some of the water in the bucket flows into the hose. The water level in the left-hand side of the hose is always exactly the same as the water level in the bucket. By the time the bucket has been raised to the outlet level, the hose is full of water up to this level. When the bucket is raised higher, water flows from the outlet. The arrangement acts as a siphon. Water continues to flow until the water level in the bucket has fallen to the same level as the outlet. Then it will stop, and the bucket will have to be lowered again for a refill.

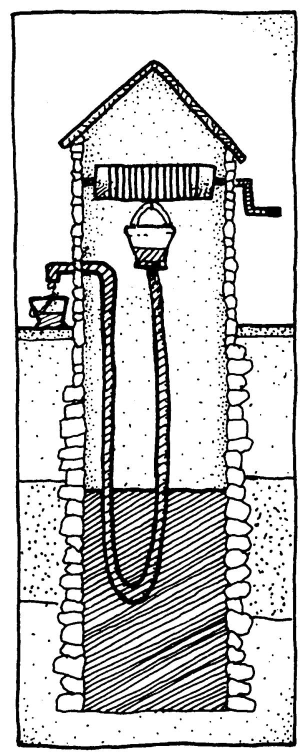
Figure 11

3 The displacement pump (Figure 12)

When the handle is pushed down, the piston rises in the guide pipe. The pressure of the water under the piston drops slightly. This makes valve 1 open, and valve 2 closes. Water flows into the guide pipe.

When the handle is pulled up, the piston is pushed down in the guide pipe. The pressure of the water under the piston rises slightly. This makes valve 1 close, and valve 2 open. Water flows into the rising main, and through the outlet.

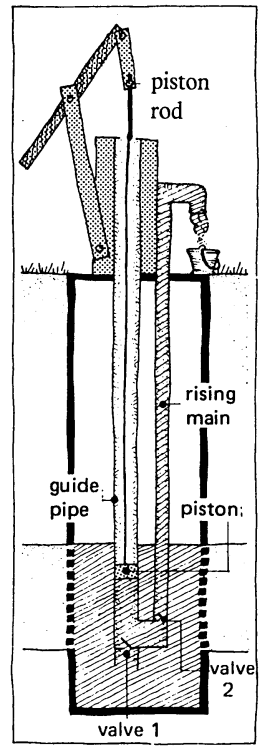

Figure 12