A Medicine to Control Bilharzia
Part 1: How can we control bilharzia?

Contents: Reading, questions and discussion concerning the nature of a tropical disease, and approaches to its control.

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

Intended use: GCSE Biology and Integrated Science. Links with work on parasitism and prevention and cure of disease.

Aims:

- To complement and revise work on parasitism and disease
- To develop awareness of the scale and impact of a major tropical disease
- To develop awareness of various approaches to the prevention and cure of tropical disease
- To provide opportunities to practise skills in reading, comprehension and application of knowledge to solving problems.

Requirements: Students' worksheets No. 304

This passage of reading and associated questions could be done for homework or in class. The advantage of class use is that students could discuss some of the questions in small groups.

Notes on some of the questions

Q.1 Students should attempt to answer this themselves before going on to the next section, which gives answers.

Q.5 This question is intended to raise the problem of economic effects on a community of a debilitating disease like bilharzia.

Q.6 It is hoped that students will realize that disease control is best approached on several fronts. Education and improved hygiene are the best hope in the long run, but in the shorter term, treatment with medicine is important.

Q.11 This question is intended to bring out the point that increased irrigation, which is vital for the improvement of agriculture, is also likely to increase the amount of infected water.

Acknowledgements Figure 1 is adapted from *Manson's Tropical Diseases* (18th edn) by P.E.C. Manson-Bahr and F.I.C. Apted (Bailliere Tindall); Figure 5: photo provided by Professor G. Webbe, London School of Hygiene and Tropical Medicine.

A MEDICINE TO CONTROL BILHARZIA — Part 1

What is bilharzia?

This unit is about a disease which is very common in tropical countries. Doctors call the disease **schistosomiasis** or **bilharzia**. It is sometimes called 'snail fever', because water snails play a part in spreading the disease.

The map in Figure 1 shows the parts of the world where bilharzia is common. You can see that most of the countries affected are in the poorer, developing parts of the world.

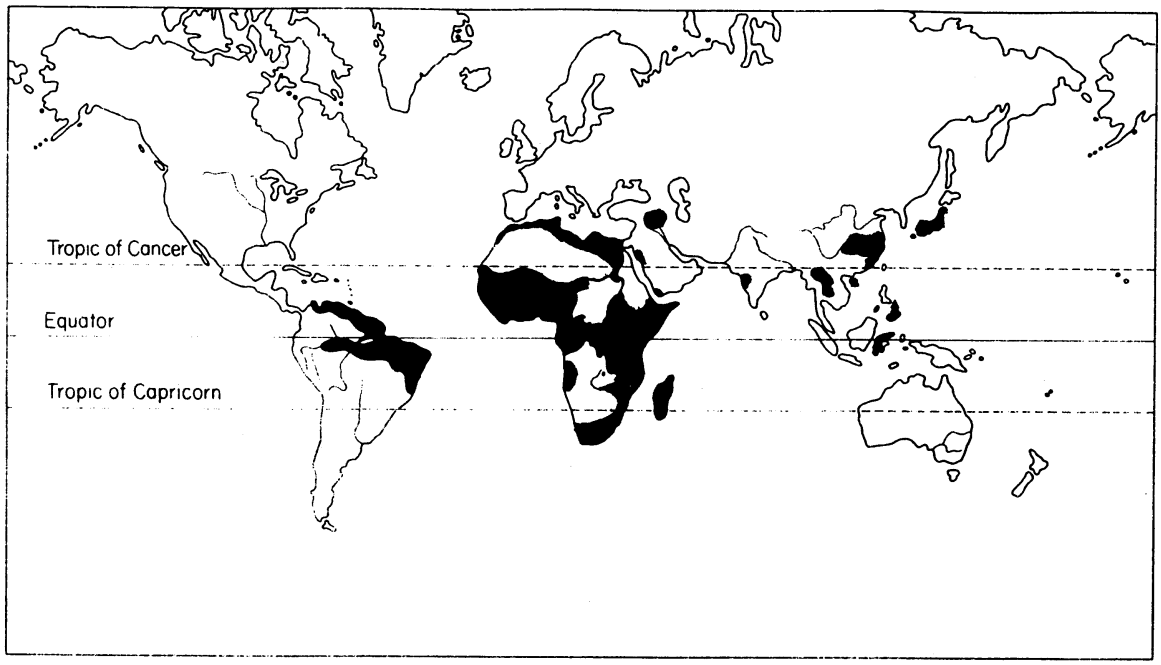

Figure 1 The parts of the world where bilharzia occurs are shown in black

Doctors believe that throughout the world about 200 million people are infected with bilharzia. This is nearly one in 20 of the world's population.

Bilharzia does not often kill, but it weakens the sufferers and makes them lethargic and short of energy. The symptoms of the disease include a swollen abdomen, diarrhoea and loss of blood. Because adult sufferers feel lethargic, it is hard for them to work. This makes it difficult for them to support their families. In some communities, 95 per cent of the population may be infected. This drags down the whole community.

This unit looks at the causes of the disease, and different ways of controlling it. Unit 305, *A Medicine to Control Bilharzia — Part 2,* looks at how a particular medicine was developed to treat the disease.

How can we control bilharzia?

What causes bilharzia?

Bilharzia is an infective disease. Like all infective diseases, it is caused by a living organism. Most common diseases are caused by bacteria or viruses, but bilharzia is caused by a blood fluke.

The blood fluke is a parasite. It lives in the blood vessels of the sufferer (called the host). Scientists call these parasites **schistosomes** (pronounced *shis-toe-soams*).

There are several different kinds of blood fluke. Each causes a different type of bilharzia. In the type of disease described here, the blood fluke lives in the blood vessels of the walls of the intestine of humans. The male and female live together. They are about 1cm long. The male wraps itself like a thin leaf around the female as shown in Figure 2.

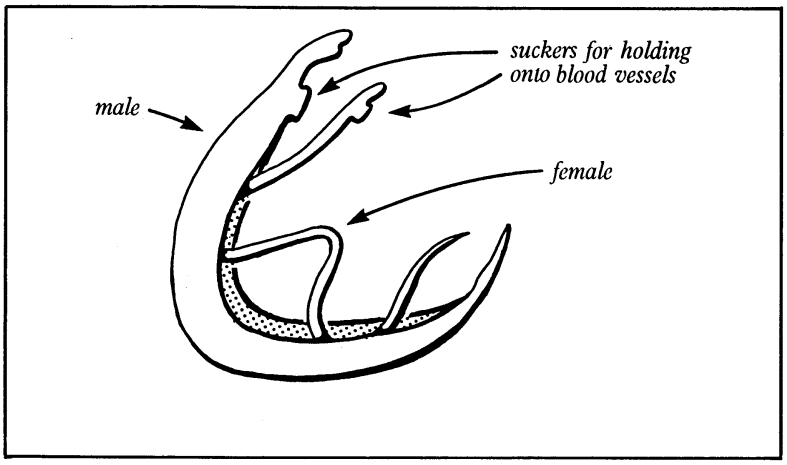

Figure 2 A male and female schistosome

The female continuously releases eggs into the bloodstream. Some of the eggs work their way through the walls of the intestines. This irritates the intestines, and may cause diarrhoea and bleeding. Other eggs settle in the liver and reduce its efficiency. The eggs which manage to get into the intestines are eventually passed out in the faeces. If the faeces reach fresh water, the eggs hatch out.

The life cycle of the blood fluke

The blood fluke which lives in humans is only one part of a fascinating life cycle. The blood fluke is the adult stage. The rest of the cycle occurs in water. Figure 3 summarizes the cycle.

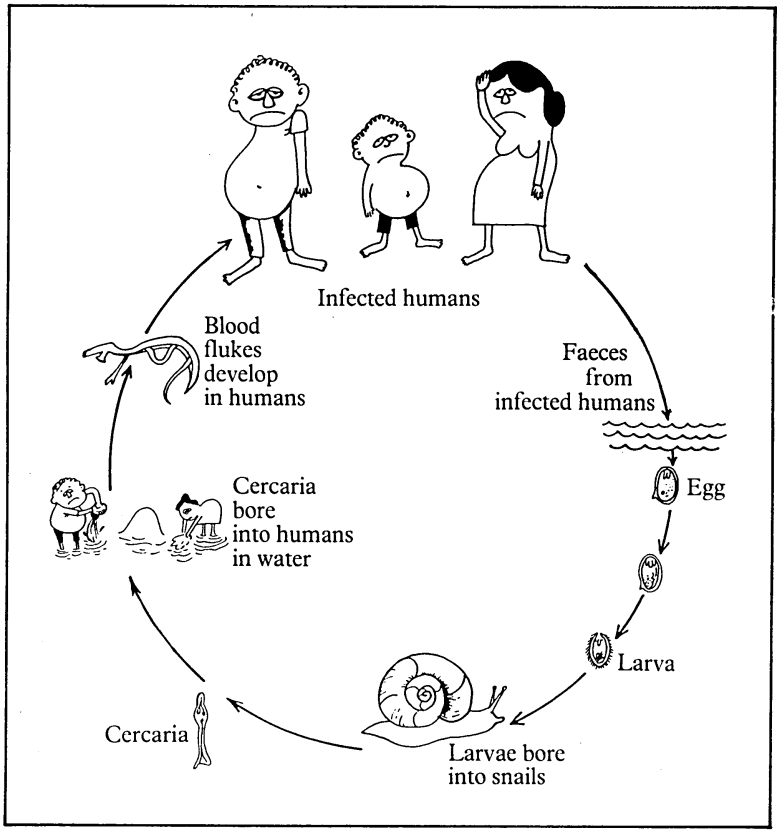

Figure 3 The life cycle of the bilharzia blood fluke

When eggs from an infected human reach fresh water, they hatch out. Tiny larvae are formed, which can swim in the water. They swim around in search of a particular kind of water snail, which is the **intermediate host**. Without the snail, the life cycle cannot continue.

The larvae bore their way into the snail. Inside, they reproduce to form thousands of little second-stage larvae called **cercariae**. These are yet another stage in the life cycle. Cercariae have a muscular tail which makes them able to swim. They wriggle out of the snail into the water. Then they go in search of a human host. This person might be wading in the water to wash, bathe or plant rice.

When they find a human host, the cercariae bore through the skin into the bloodstream. When they reach the blood vessels of the hosts's intestine, they feed and grow into adult blood flukes. These adults produce eggs, and the whole life cycle begins again.

Before you go on, try to answer question 1.

Question

1 *Now that you have read about the blood fluke's life cycle, you may have thought of some ways of solving the problem of how to control bilharzia. There are several possible solutions. Suggest as many different ones as you can.*

Solving the snail fever problem

There are several possible ways of controlling the disease. They work on different parts of the life cycle (Figure 4).

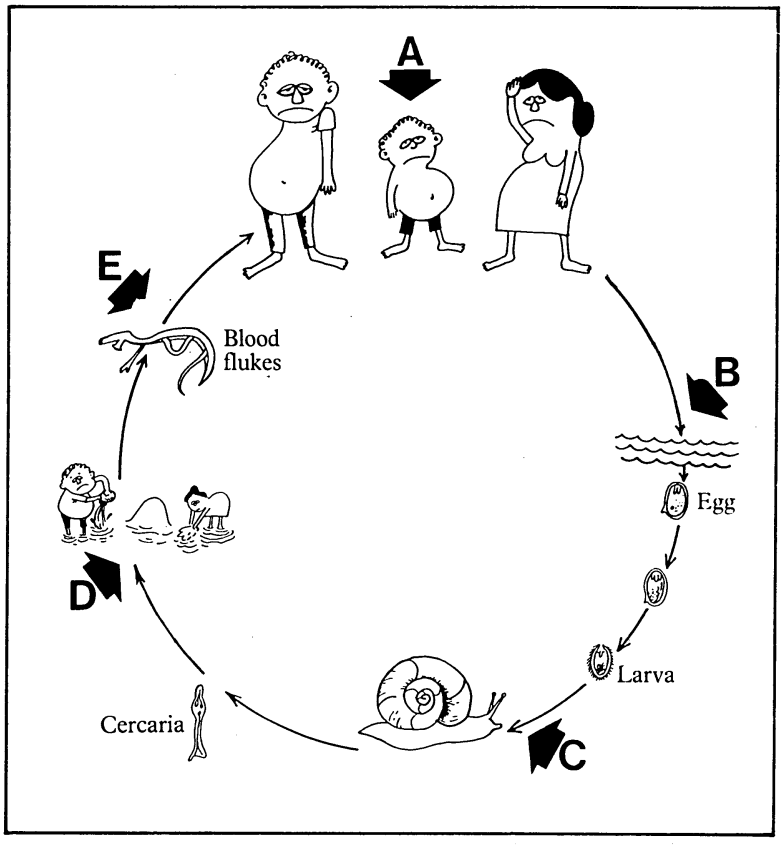

Figure 4 Bilharzia can be controlled at different parts of the life cycle

A *Immunization* One possibility would be to immunize (vaccinate) people against the disease by giving them an injection.

B *Better sanitation* The eggs get into the water when the faeces from infected people are allowed to pollute water. Better toilet arrangements help stop the spread of eggs.

C *Getting rid of the snails* Water snails are the intermediate host in the life cycle. Without them, the disease cannot spread. If the snails can be killed, the disease can be controlled.

D *Keeping people away from infected water* If snail-free water can be provided for washing and bathing, this helps cut down infection.

E *Using medicines to treat infected people* These medicines work by killing the blood flukes in the host's blood vessels. In *A medicine to Control Bilharzia — Part 2* you can find out more about one such medicine, called 'Compound X'.

However, experience shows that no single method will wipe out the disease. Several methods have to be used together.

Before you go any further, try to answer questions 2 to 4.

Questions

2 *For each of the control methods, suggest one* disadvantage *which you think that method might have.*

3 *Which method or combination of methods do you think would be best to use in the long run? Explain why you think this is best.*

4 *Can you think of any other control methods not mentioned here?*

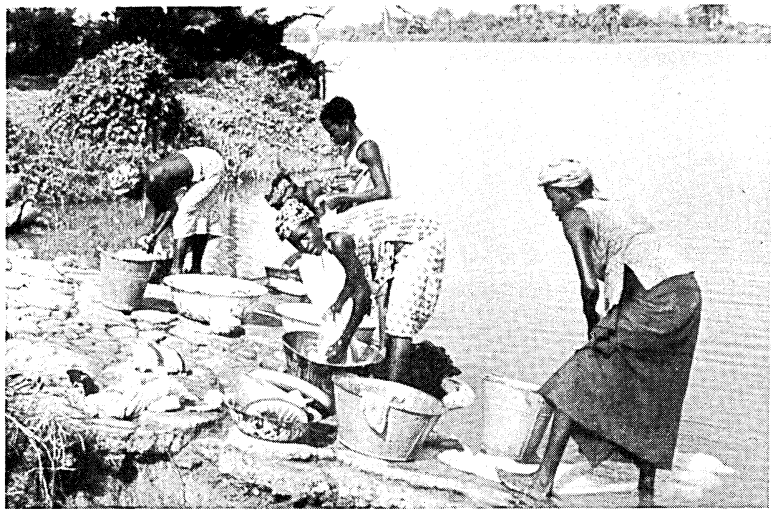

Figure 5 Washing in a river in West Africa. But the water could be infected with bilharzia

Which methods actually work?

We will look at each of the methods **A** to **E** in turn.

A Doctors have tried to develop ways to immunize people against bilharzia, but they have not yet been successful.

B Providing good toilet arrangements can be expensive. However, it is very important because it helps control other diseases such as typhoid and dysentery as well as bilharzia.

C Scientists have tried many different ways of getting rid of the water snails. Some chemicals will do this, but they have to be used in large quantities to treat all the water. This can be very expensive. There is also the problem that the chemicals may affect other forms of life as well, for example, fish. Biological control has been tried. For example, some larger species of snails will feed on the smaller intermediate host snail. So far, attempts to control the snails chemically or biologically have not been very successful.

D Keeping people out of infected water would be very effective. Education is important. If people know what causes the disease, they will know the importance of keeping away from infected water. Irrigation systems are often infected. As a country develops its agriculture, it is likely to build more irrigation systems, which increase the problem.

E Medicines can be very effective in controlling the disease. 'Compound X' cures about 85 per cent of patients treated. Once patients have been cured, they no longer produce eggs in their faeces. This helps cut down the disease still further. One problem with medicines is that they can have unpleasant side-effects. As new medicines are developed, attempts are made to cut down the side-effects.

Answer questions 5 to 11. You may like to discuss them in small groups or with the rest of the class.

Questions

5 *Why is it important to control bilharzia, even though it does not usually kill people?*

6 *Suppose you are Minister of Health in a developing country. You are determined to control bilharzia, but you only have a small amount of money to spend. What would you do? Suggest a 'ten-year plan', aiming to control the disease in ten years.*

7 *Why is it important for a country to eradicate diseases such as bilharzia if it is to develop its economy?*

8 *The snails and blood flukes which cause bilharzia do not occur in Britain. Suggest one reason why not.*

9 *Suppose the snails and blood flukes which cause bilharzia* did *occur in Britain. Do you think the disease would spread quickly? Explain your answer.*

10 *Explain in your own words how education can help control bilharzia.*

11 *Explain in your own words how agricultural development can help to spread bilharzia.*

A Medicine to Control Bilharzia
Part 2: Developing a medicine to control bilharzia

Contents: Reading, questions and discussion concerning the development, testing and production of a pharmaceutical product for the control of a tropical disease.

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

Intended use: GCSE Chemistry, Biology and Integrated Science. Links with work on carbon compounds in chemistry, and work on disease control in biology.

Aims:

- To complement work on carbon compounds and on disease
- To develop awareness of the scale and impact of a major tropical disease
- To show the stages by which a pharmaceutical product is developed, through synthesis, testing and safety screening to a large-scale manufacture
- To provide opportunities to practise skills in reading and comprehension, and to encourage readiness to enter into discussion.

Requirements: Students worksheets No. 305

This passage of reading and associated notes could be done for homework or in class. The advantage of class use is that students could discuss some of the questions in small groups.

Notes on some of the questions

Qs 2 and 3 'Compound X' differs from 'Compound A' only in the presence of an OH group on the methyl group attached to the benzene ring. The hydroxylation of this group and no other is difficult to achieve chemically. In practice a biological fermentation method is used.

Qs 4 to 7 and 14 Many children have strong feelings about the use of animals in research. Attempts are being made to find alternatives to animal testing, for example, using cell cultures. But the problem is that once inside the body, medicines undergo many complex metabolic changes. It is difficult to see the whole picture of the medicine's effects without testing the medicine on whole live animals. The majority of experiments are done on mice, but to get a good idea of the behaviour of a medicine in humans, it is desirable to test it on other animals, like rabbits, cats, dogs and monkeys, which are closer to humans. Medicines are not tested on humans until their safety has been demonstrated to an acceptable level in several species.

Q.8 Medicines are tested on healthy people first because they are better able than sick people to sustain any unexpected side-effects.

Q.10 The proportion of para-toluidine converted to Compound X would be $(0.5)^6 = 0.015625$. Thus to produce 1 molecule of Compound X, $1/015625 = 64$ molecules of para-toluidine are needed.

Q.12 This question is intended to bring out the problem of developing sophisticated pharmaceuticals in a country with a small scientific and technological base.

Acknowledgements Figure 1 adapted from *Manson's Tropical Diseases* (18th edn) by P.E.C. Manson-Bahr and F.I.C. Apted (Bailliere Tindall); Figure 5: photo provided by Pfizer Central Research.

A MEDICINE TO CONTROL BILHARZIA — Part 2

What is bilharzia?

This unit is about a disease which is very common in tropical countries. Doctors call the disease **schistosomiasis** or **bilharzia**. It is sometimes called 'snail fever', because water snails play a part in spreading the disease.

The map in Figure 1 shows the parts of the world where bilharzia is common. You can see that most of the countries affected are in the poorer, developing parts of the world.

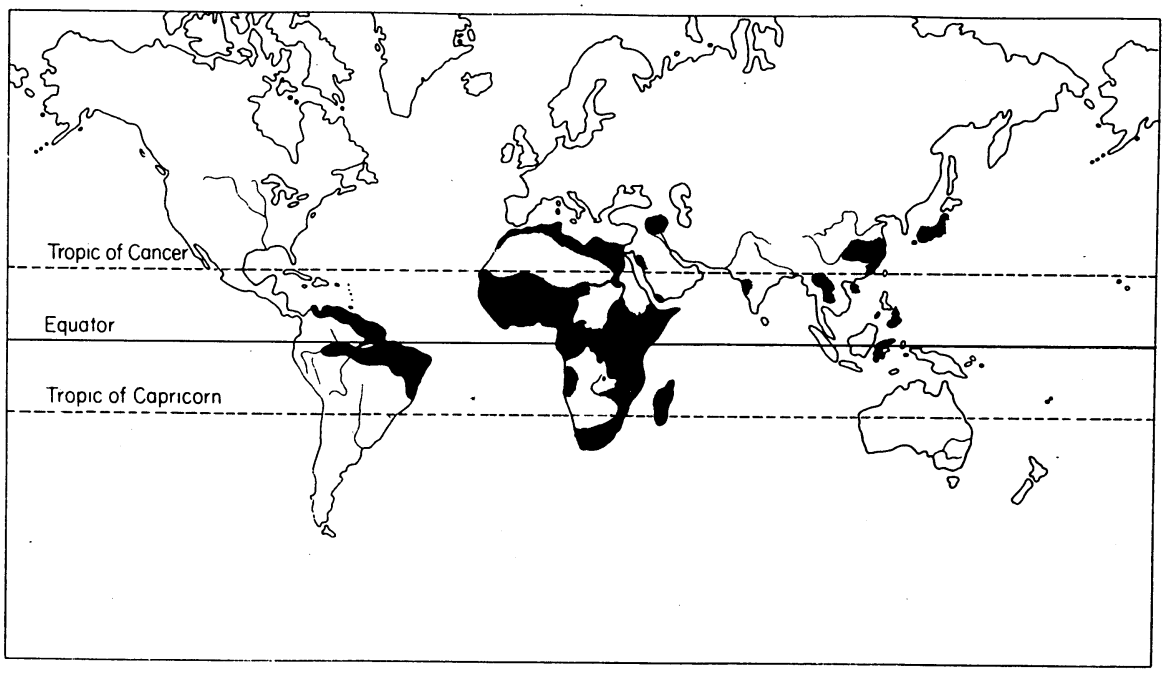

Figure 1 The parts of the world where bilharzia occurs are shown in black

Doctors believe that throughout the world about 200 million people are infected with bilharzia. This is nearly one in 20 of the world's population.

Bilharzia does not often kill, but it weakens the sufferers and makes them lethargic and short of energy. The symptoms of the disease include a swollen abdomen, diarrhoea and loss of blood. Because adult sufferers feel lethargic, it is hard for them to work. This makes it difficult for them to support their families. In some communities, 95 per cent of the population may be infected. This drags down the whole community.

This unit looks at how a particular medicine was developed to control bilharzia. Unit 304, *A Medicine to Control Bilharzia — Part 1*, looks at the causes of the disease, and different ways of controlling it.

Developing a medicine to control bilharzia

If you have used *A Medicine to Control Bilharzia — Part 1*, you will know that bilharzia is caused by a blood fluke. This parasite lives in the victim's blood vessels. There are several ways of controlling the disease. An important way is to give the patient a medicine which kills or paralyses the blood flukes. This part of the unit is about the development of such a medicine, called 'Compound X'.

The stages in developing a new medicine

Medicines are made by pharmaceutical companies. As well as making medicines, pharmaceutical companies are always trying to develop new ones. Developing new medicines takes a long time. Compound X took over ten years to develop. One of the main reasons for this is the need to test any new medicine very carefully. First the medicine must be tested to make sure it works and controls the disease in the laboratory. It must also be tested to make sure it is safe and does not have any serious side-effects. These tests are done on animals first, then humans.

The main stages in developing a new medicine are shown in Figure 2. In fact several of these stages overlap.

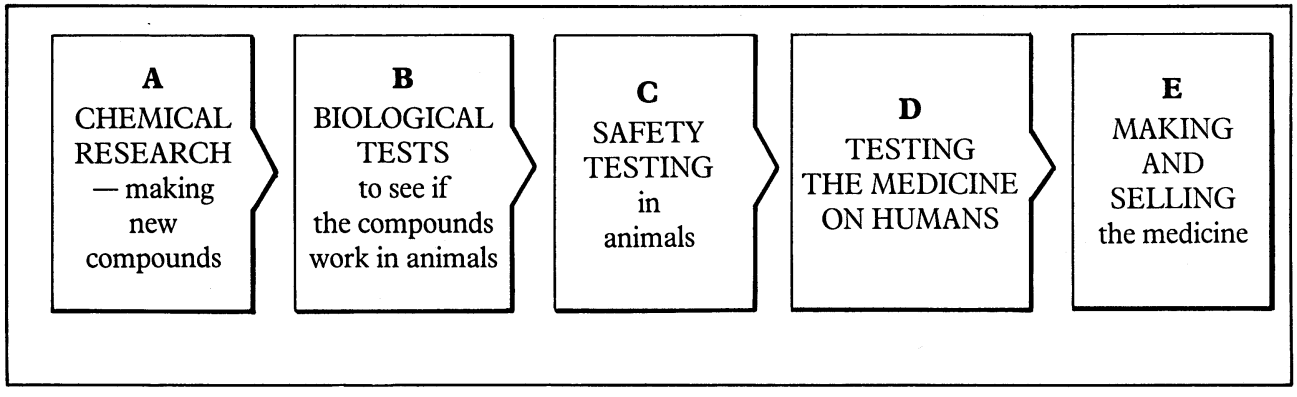

Figure 2 The main stages in developing a new medicine

A Chemical research

All medicines are chemical compounds. Almost all of them are organic compounds, containing carbon and hydrogen. In looking for a medicine to cure bilharzia, the trick is to look for compounds that will poison blood flukes but will not harm humans.

When the search began, some medicines already existed for treating bilharzia. But they had disadvantages — mainly in the form of unpleasant side-effects.

Chemists began by making compounds that were similar to one of the medicines already being used. These compounds were given to laboratory mice which were suffering from bilharzia. One compound, which we will call 'Compound A', was found to be very good at controlling the disease in mice.

The chemical structure of 'Compound A' is shown in Figure 3. Answer question 1.

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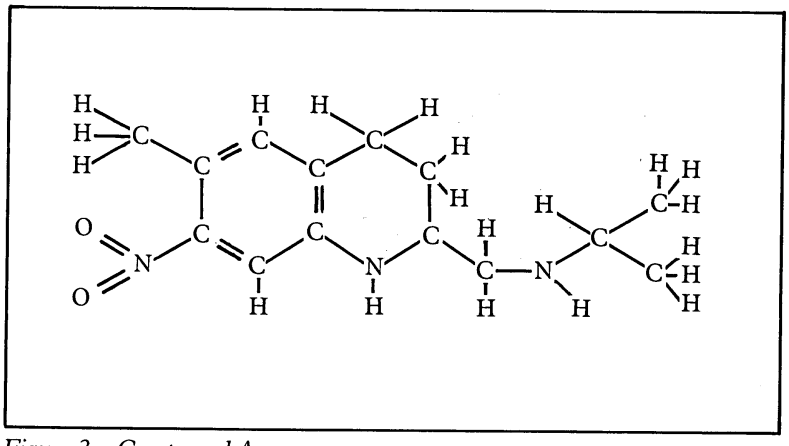


Figure 3 Compound A

Question

1 *What is the molecular formula of Compound A? (The molecular formula gives the number of each type of atom, but not their arrangement. For example, the molecular formula of sulphuric acid is H_2SO_4.)*

B Biological tests

Compound A was promising, so more investigations were made on it. Biological tests showed that it was not actually Compound A itself that was active in controlling the disease.

Once a medicine has been taken by a patient, it is metabolized. This means chemical changes happen to it inside the patient's body. More tests on animals showed that Compound A was changed to a new substance in the liver. We will call this new substance 'Compound X'. Compound X is the active compound that poisons the blood flukes.

The chemical structure of Compound X is shown in Figure 4. Answer questions 2 and 3.

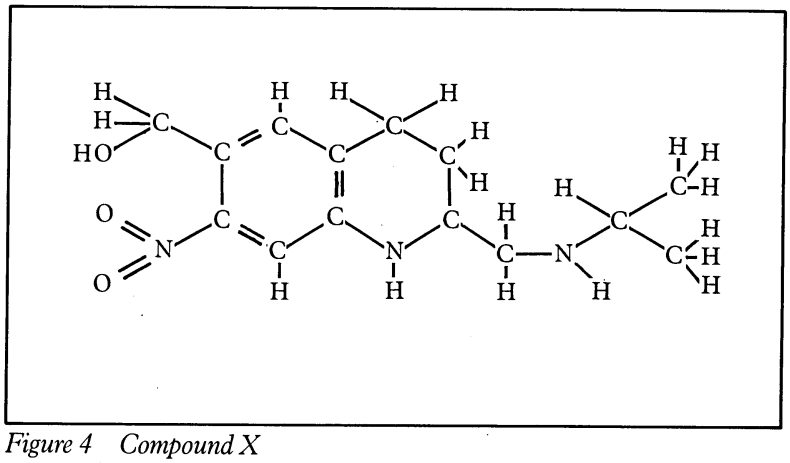


Figure 4 Compound X

Questions

2 *Look closely at the structure of Compound X. Compare it with Compound A. What difference is there between the two compounds?*

3 *What would chemists have to do to turn Compound A into Compound X? Why might this be difficult? (We will return to this question when we look at the manufacture of the medicine.)*

Compound X was so effective at controlling the disease in the laboratory that it was decided to test it further. Many more biological tests had to be done, to find out what would happen to Compound X in the patient's body. At this stage the medicine had not yet been tested in humans, only in animals. Before it could be tried in humans, it had to be tested for safety.

C Safety testing

Some medicines have side-effects that only show after a long time. Safety studies therefore have to be carried out over several years.

The medicine is first given to animals. It is given in doses far greater than would be given to humans. The animals are then checked for side-effects. Safety tests are first carried out in mice. If the tests on mice are successful, the medicine is tested in larger animals such as monkeys.

Of course the animals may suffer during the safety tests. All animal testing laboratories are frequently visited by government inspectors. These inspectors check to see there is no unnecessary suffering.

After the tests, the animals are usually killed and examined to find out what effect the medicine has had on different organs.

Answer questions 4 to 7.

Questions

4 *Why are the first safety tests done on animals, not humans?*

5 *Why are mice used before larger animals?*

6 *Why can scientists find out more by testing in monkeys than by testing in mice?*

7 *Are there other ways, not using animals, that medicines could be tested for safety?*

D Testing the medicine in humans

The only way of making sure a medicine is safe and effective is to test it in humans. After Compound X had passed the animal safety tests, it was tested on healthy human volunteers who were not suffering from bilharzia. The volunteers are given small doses at first, which are gradually increased.

If these first human tests are successful, the medicine goes for clinical trials. In the case of Compound X, this meant giving the medicine to people who were actually suffering from bilharzia. Doctors follow these trials carefully, to check how well the medicine works, and whether it has side-effects. Only after successful clinical trials can the medicine get a licence which allows it to be sold.

Answer questions 8 and 9.

Questions

8 *Why is the medicine tested in healthy people before it is used in patients?*

9 *Would* you *volunteer to try out a new medicine?*

E Producing and selling the medicine

Once the medicine has a licence, it can be sold and used generally. This means that ways must be found to make large quantities of the medicine. This can be very complicated and can involve many steps.

In the case of Compound X, the starting point for production is a chemical called para-toluidine. This is a fairly common and readily available chemical. It can be turned to Compound A in five chemical stages. Compound A is then converted to Compound X (Figure 5).

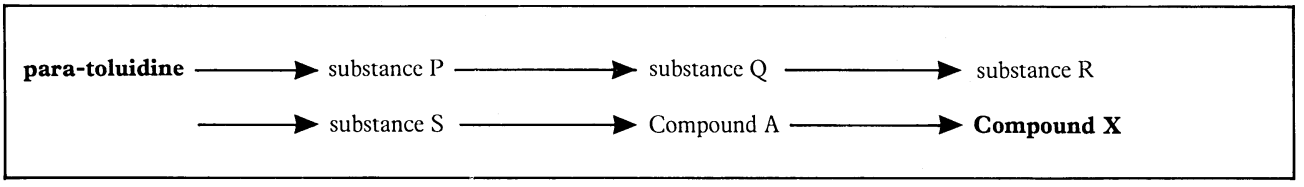


Figure 5 Converting para-toluidine to Compound X

The most difficult stage to carry out is the last one. You will have realized that the only difference between Compound A and Compound X is that Compound X has an extra OH group. To put this on in the right place using a chemical reaction is difficult. Fortunately this step can be done using microbes. Under the right conditions, certain microbes will turn Compound A to Compound X. This is an example of the way **biotechnology** can be used to make substances we need.

Answer question 10.

Question

10 Chemical conversions are never 100 per cent efficient. Suppose each of the six stages in the production of Compound X was only 50 per cent efficient. This means that at each stage, only half the molecules of one substance are turned to the next substance. How many molecules of para-toluidine would you need to start with in order to make 1 molecule of Compound X?

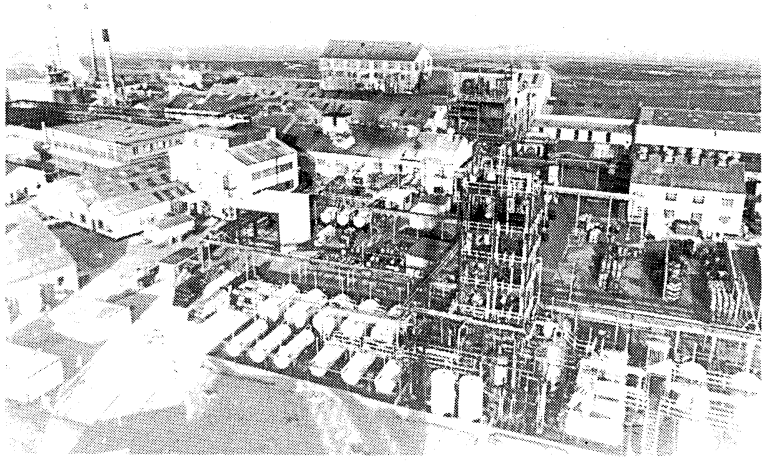


Figure 6 Factories for making pharmaceutical products are often large and complex

Compound X in action

Compound X is widely used to control bilharzia in Africa and South America. A single dose taken by mouth is enough to cure about 85 per cent of patients. Its only side-effect is to cause slight dizziness in some patients. After being cured, patients still run the risk of getting reinfected if they go into contaminated water.

Answer questions 11 to 14. You may like to discuss them in small groups or with the rest of the class.

Questions

11 Pharmaceutical companies make and test many chemical compounds to see if they will make useful medicines. For every compound that becomes a useful medicine, about 10 000 compounds are tested and rejected. Give some of the reasons why a compound may be rejected.

12 Compound X was developed and manufactured in Britain, but it is only used in tropical countries. Why was it not developed by these countries themselves?

13 From what you have heard of Compound X, could it be improved? In what ways could other medicines be made which were better?

14 Developing and testing medicines like Compound X means suffering and loss of life for laboratory animals. Do the benefits of the medicines justify this?

Fibre Optics and Telecommunications

Contents: Reading and questions on the use of optical fibres in telecommunications.

Time: 2 periods.

Intended use: GCSE Physics and Integrated Science. Links with work on light, internal reflection, refractive index and waves.

Aims:

- To complement work on light and internal reflection
- To develop awareness of the past, present and future development and importance of telecommunications
- To show the importance of fibre optics technology in telecommunications
- To develop awareness of the effect of new technologies on society
- To provide opportunities to practise skills in reading, comprehension and communication.

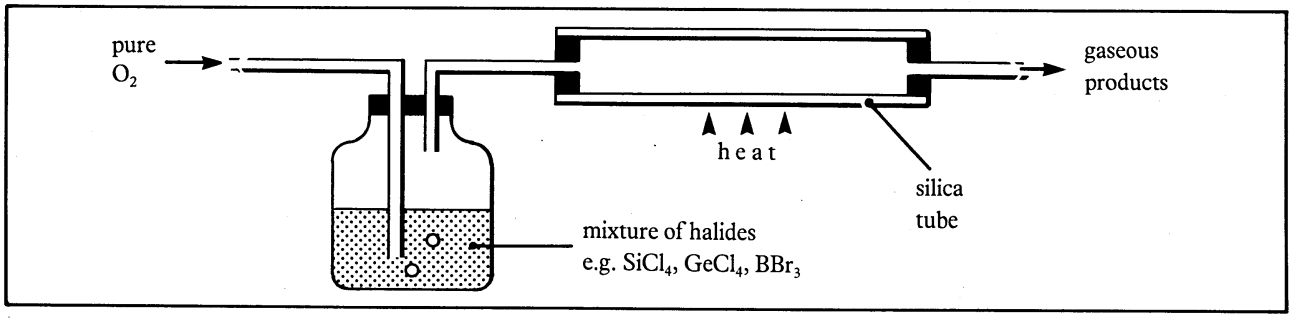
Requirements: Students' worksheets No. 306. It would be helpful to have samples of optical fibre available (see 'Other Resources').

Manufacture of optical fibre

The following information is provided for the teacher, but could be passed on to students if the teacher wished.

The basic principle of manufacture is to draw out a thin fibre from a heated rod of much wider diameter. This 'pre-form' rod must be very accurately made of extremely pure glass. One method of pre-form manufacture involves depositing the glass on the inside of a silica tube. The glass is formed *in situ* by a reaction between halides and oxygen. For example:

$$SiCl_4 + O_2 \longrightarrow SiO_2 + 2Cl_2$$



By varying the composition of the mixture of halides, the composition of the glass can be changed. This in turn varies the refractive index of the glass. Using extremely pure chemicals, and depositing the glass on the *inside* of the tube, keeps contamination by impurities to a minimum.

Notes on some of the questions

Q.4 The advantages of optical fibres mentioned in the students' worksheets are:

(a) Less loss of signal strength, so boosters can be further apart.

(b) Ability to carry large numbers of simultaneous conversations — thousands in the case of a single optical fibre, compared with tens in the case of a single copper wire.

(c) Freedom from interference.

(d) Smaller size and weight.

(e) Optical fibres are made from virtually limitless resources and are potentially cheaper than copper wire. Technological development has helped bring down the price of fibre: between 1982 and 1984 the price of fibre fell from £2000 to £200 per kilometre.

Q.8 Possibilities that could be mentioned here include satellite communication, which is a development already under way; videophones, which combine visual and aural communication; and electronic mail, in which messages arrive at a computer terminal via the telecommunications network. It might be interesting to discuss whether telecommunications will ever replace postal services. Improved telecommunications may lead to changes in travel habits with more people working at home, and increased use of 'video-conferencing'.

Q.9 There are of course many factors which operate to influence the pace and timing of technological development. These include:

(a) The needs of society (telephones would have been of limited value to medieval society, even if they had been a technological possibility, but they filled a need in the nineteenth century).

(b) The state of existing scientific knowledge (clearly telephones could not develop before discoveries concerning electricity).

(c) The state of existing technological knowledge and skill (without the necessary technological skills, glass fibres of suitable purity and accuracy for telecommunications purposes could not have been manufactured, even though the principle was well established).

As a matter of interest, Alexander Graham Bell himself patented a light-communication device called the 'Photophone' in 1880. Bell focused light (from the Sun, a lamp or even a candle) into a beam which was passed through a rotating wheel which 'chopped', or modulated it. The transmitter consisted of a microphone diaphragm connected to this modulator. The receiver used light-sensitive selenium to convert the modulated light to electrical signals. Obviously Bell's Photophone suffered from a number of serious limitations, not least the need for a strong light source and an uninterrupted path for the light beam.

Q.10 Telecommunications illustrate the 'chicken or egg' situation that developing countries are often in. Without a good system of telecommunications, development is held back, yet without development it is difficult to provide the resources needed to install such a system.

Notes for the teacher on the simultaneous transmission of telephone conversations

Some students may be interested to find out how conversations can be transmitted simultaneously, and why optical fibres make it possible to transmit larger numbers of conversations. The following notes may help.

To understand a telephone conversation you do not need to hear the signal the whole time. If the amplitude of the electrical signal is sampled every 125 microseconds then enough information has been gathered for the receiver to reconstruct the original conversation. Each of these samples lasts only 3 microseconds and so there is time to send short bursts of about 40 conversations each sampled in turn. Putting in suitable gaps between samples to avoid confusion leaves you with room for 32 separate conversations.

The sample amplitudes are converted into binary form and transmitted as on-off pulses. Digital coding reduces the seriousness of the inevitable distortion and loss of strength down the line. The receiver can recognize a feeble pulse as a 1, takes everything else as zero and so can restore the signal. This digital system, called 'Pulse Code Modulation', is used on many BT trunk lines and all optical fibre links.

To increase the number of simultaneous conversations carried by a link, the binary code pulses must be closer together. This means that the transmission medium (for example, a cable) should be capable of carrying a high frequency without blurring the pulses to the extent that they overlap. A coaxial cable and microwaves can deal with frequencies up to 100 MHz, but a glass fibre should do better because it transmits light of frequency 10^8MHz. At present, the laser and detector cannot cope with frequencies above 500 MHz (which is still much better than coaxial cable), but future devices should enable the huge potential capacity of optical fibres to be used.

For further details on PCM and optical fibres, see note below on *Telecommunications in Practice.*

Other resources

Video Programmes

1 'The Photon Connection' is a video recording of the 1983 Faraday Lecture on optical communication, and an entertaining introduction to the subject. It runs for 33 minutes and is available on free loan from: Central Film Library, Chalfont Grove, Gerrards Cross, Bucks SL9 8TN.

2 'The History of the Telephone' is a lively programme available on free loan from: British Telecom Film Library, 25 The Burroughs, Hendon, London NW4 4AT.

Telecommunication in Practice, a joint publication by the Association for Science Education and British Telecom, is a useful source of information, including experimental work on optical fibres. Available from: ASE, College Lane, Hatfield, Herts AL10 9AA.

Optical fibres in school physics, a title in the 'Experimenting with Industry' series, has useful information and experimental work. Available from the ASE.

The Telecom Technology Showcase traces the historical development of telecommunications, and also displays some of the latest developments in communications technology. It is situated at: British Telecom, Baynard House, Queen Victoria Street, London EC4. Tel. 01-248 7444. Visits can be booked in advance. Admission free.

Visits to local telephone exchanges. These are very worthwhile, and easily arranged. Simply dial 100 and ask to speak to the supervisor.

Samples of optical fibre can be obtained free of charge by writing to: Marketing Manager, GEC Optical Fibres, Church Road, London E10 7JH. These could be examined under the microscope and used for light transmission experiments.

Acknowledgements Figure 1 from Telefocus: a British Telecom photograph; Figure 5 reproduced by permission of the Department of Trade and Industry.

FIBRE OPTICS AND TELECOMMUNICATIONS

A little history

Humans have always needed to communicate with one another. At first they could only communicate when they met, but later they found ways of communicating at a distance.

Messengers were used to carry communications, and in the nineteenth century the first postal services began. These meant every person could communicate with people far away if they wanted.

In the mid-nineteenth century the Electric Telegraph was developed. This used electric currents to send messages in Morse code long distances along wires. In 1876 Alexander Graham Bell first demonstrated his telephone. This new invention meant that people could actually talk to each other at a distance.

Figure 1 An early telephone, in use from about 1914

The telephone was a great advance in communications technology. When you speak into a telephone mouthpiece, sound signals are converted to electrical signals. These electrical signals pass along a copper wire to the telephone receiver. Here they are converted back to sound signals in the earphone (Figure 2 on the next page).

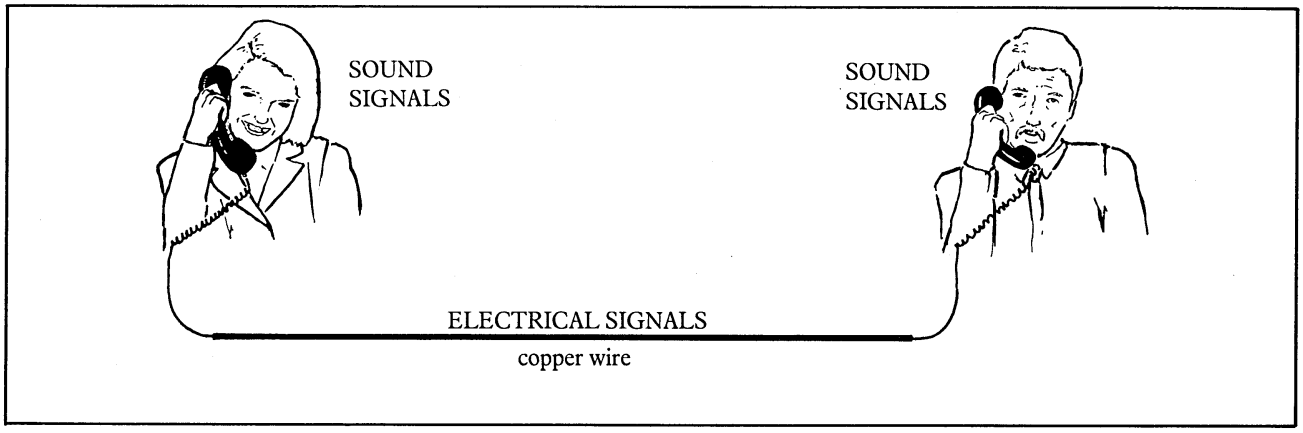


Figure 2 How a telephone sends and receives signals

By the middle of the twentieth century, thousands of kilometres of copper wiring were carrying telephone conversations all over the world. In 1925 there were 2.8 telephones per hundred people in Britain. By 1950 the figure was 10.2, and in 1981 it was 50.

But there are problems with using copper wires to carry conversations.

- The number of conversations that can go down a wire at one time is limited. If you want to carry more conversations, you need more wires.
- The signal carried along the wire gets weaker the further it goes. This means telephone cables need 'boosters' every 2 or 3 km to strengthen the signals.
- Copper wires are heavy and take up quite a lot of space in their underground channels.

Questions

1 *What difference would it make to your family's life if telephones did not exist?*

2 *Choose one business or company which you know about. What difference would it make to them if telephones did not exist?*

Optical fibre communications

Optical fibres are rapidly replacing copper wires as a way of carrying telecommunications. In this unit you will find out why.

Light has long been used for communications. Semaphore signals, beacons, flashing lights and the smoke signals used by the North American Indians are all examples. But the main problem is that light travels in straight lines. If something gets in the way, you cannot see the light signals.

Optical fibres were first developed in the 1960s. They enable light to go round corners, and can be thought of as 'light pipes'.

How do optical fibres work?

If you are swimming under water, you cannot usually see the sky. Light is reflected back from the under-surface of the water. This is **total internal reflection**. It happens because air and water have different **refractive indexes**.

A similar thing happens in optical fibres. The fibre is made out of two different kinds of glass. The central **core glass** is surrounded by **cladding glass**. The core glass and the cladding glass have different refractive indexes. Light travels along the central glass core. When light rays hit the boundary between the core and the

cladding, they are reflected internally back into the core. In this way, the light is kept inside the core, like water in a pipe. It does not matter if the fibre goes round corners — the light still travels inside the core.

The optical fibre is protected on the outside by a plastic coat. It is very thin — often thinner than a human hair.

Figure 3 shows the arrangement.

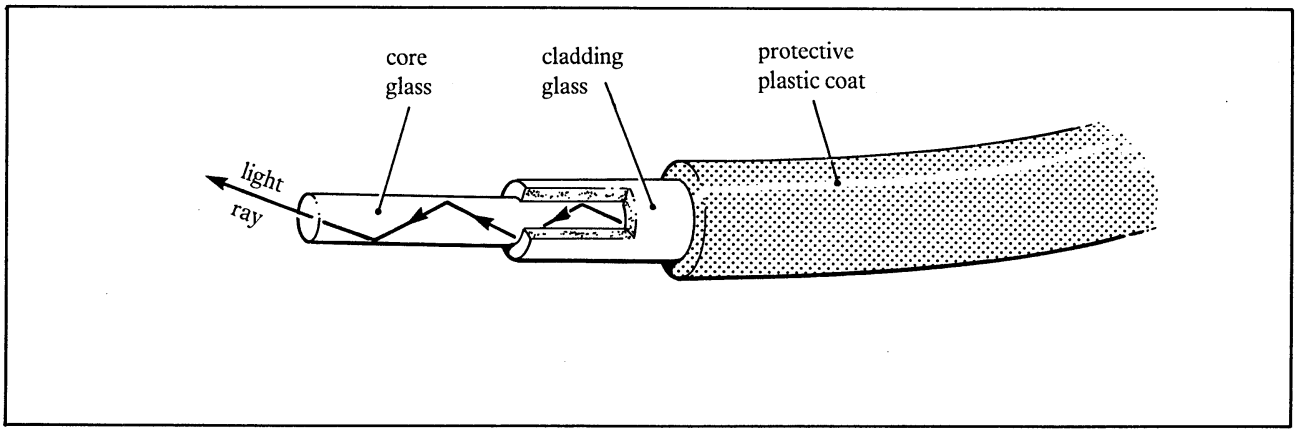


Figure 3 An optical fibre

The glass must be very pure, because impurities would scatter and absorb the light. Keeping the glass pure enough is one of the most difficult parts about making optical fibres. With suitably pure glass, laser light can travel more than a hundred kilometres along a fibre with little loss of strength. The glass used for optical fibres is so pure that you could see through a block of it 1 kilometre thick. (Ordinary glass looks black at a thickness of 1 metre.)

Using optical fibres in telephones

Optical fibres replace the copper wires used to carry telephone conversations (Figure 4).

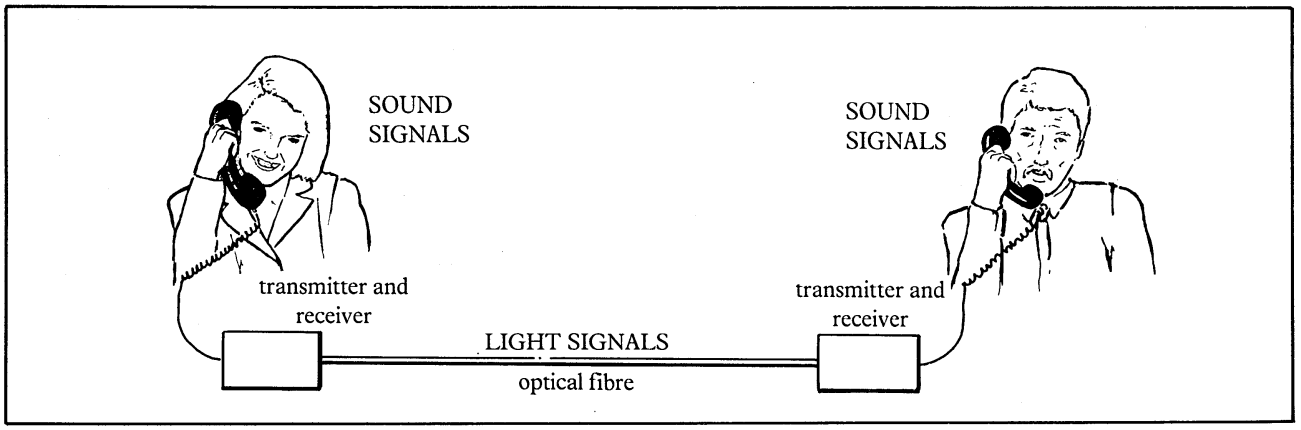


Figure 4 Using optical fibre to carry telephone signals

Signals are carried as pulses of light. The sound signals from the speaker are turned to electrical signals first, in an ordinary telephone mouthpiece. But the electrical signals are then

converted to light signals by a transmitter. At the other end of the line, the light signals are converted back to electrical signals by a receiver. These electrical signals operate the telephone earpiece in the usual way.

The signals travel along the optical fibre in the form of pulses, or flashes, of laser light. The laser light source is turned on and off very quickly. The light pulses make up a binary code which is decoded by the receiver.

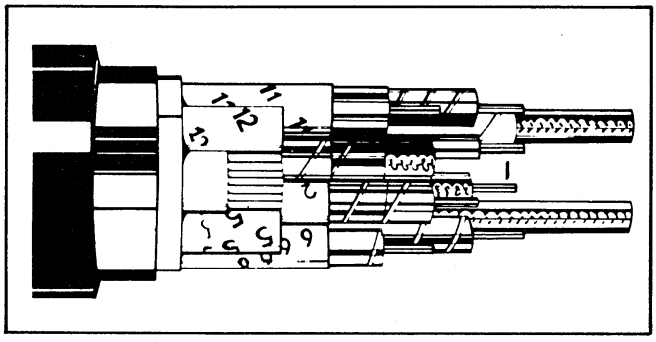
Because the laser light has a high frequency, lots of different signals can be sent at the same time. This means an optical fibre can carry many thousands of different telephone conversations at the same time. What is more, the signals stay strong for long distances. With optical fibres, 'boosters' are only needed every 30 km or more. An optical fibre is much smaller than a copper wire capable of doing the same job (Figure 5). And unlike copper wires, optical fibres do not suffer from interferences from other electrical signals.

Another advantage of optical fibres is that the raw materials for glass are plentiful, unlike copper. This means glass can be made more cheaply than copper.

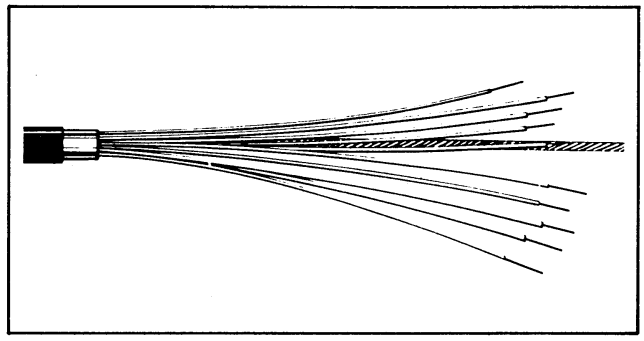
Questions

3 *What job is done by each of the following in an optical fibre communication system?*
(a) the transmitter
(b) the receiver
(c) the laser
(d) the optical fibre itself

4 *It may not seem to make much difference to you whether your telephone calls are carried by copper wires or optical fibres. But what are the advantages to telephone engineers of optical fibres over ordinary copper wires?*



Telephone cable with 10 000 call capacity — made from copper



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

Figure 5

Because of all the advantages, British Telecom is replacing copper wire by optical fibres for its telephone network all over the country. The fibres are grouped together in optical cables laid under the ground. By the end of the 1980s, most telephone calls in Britain will be carried by optical fibres.

What other uses are there for optical fibres?

Optical fibres have other applications as well as in telecommunications.

For example, in medicine, optical fibres can be used as 'light pipes' to see inside a patient's body. A bundle of optical fibres, inside a flexible tube, is inserted into, say, the stomach or the lungs, through the body's natural passages. The surgeon can then inspect the organs without having to cut the patient open.

Question

5 *Optical fibres are used to link computers together. How might this be done?*

Further questions to answer and discuss

You may like to discuss these points in small groups.

6 *New technology often replaces older technology, in the same way as optical fibres are replacing telephone wires. New technology also often has a big effect on people's lives. For* two *of the following examples of new technology, say:*

(a) Which, if any, older technology it is replacing
(b) Why it is replacing the older technology
(c) What effect it has on our lives.

(i) Electronic calculators
(ii) Videocassette recorders
(iii) Microcomputers
(iv) Digital watches.

7 *In their time, each of the following inventions were new technologies. Which older technologies did each replace?*

(a) Steam engines
(b) Polythene
(c) Roofing tiles
(d) Electric lighting
(e) Ballpens.

8 *Apart from fibre optics, what other major technological developments do you think we might see in telecommunications in the future?*

9 *Optical fibres are an example of new technology. When telephones were first invented, they also were new technology. Suggest reasons why:*

(a) Telephones were not developed before 1876
(b) Optical fibres were not developed until the 1960s.

10 *This table shows the number of telephones per hundred people in different countries.*

Country	Number of telephones per hundred people (1976)
USA	*84*
United Kingdom	*49*
Portugal	*14*
USSR	*9*
Brazil	*6*
India	*0.4*
Malawi	*0.3*

(a) Comment on these figures.
(b) In what ways can a good telephone system help the development of a country?