UNIVERSITY OF SWAZILAND
FACULTY OF EDUCATION
DEPARTMENT OF CURRICULUM AND TEACHING
FINAL EXAMINATION QUESTION PAPER, DECEMBER 2011

TITLE OF PAPER	:	CURRICULUM STUDIES IN BIOLOGY I
COURSE CODE	:	EDC 278
STUDENTS	:	BEd. II, PGCE
TIME ALLOWED	:	THREE (3) HOURS

INSTRUCTIONS: 1.This examination paper has six (6) questions. Question 1 is compulsory. Then answer any three (3) questions.

2. Each question has a total of 25 points.

3. There are two attachments (Biology for IGCSE, Jones, M., 2002, pages 258-277; and IGSE Biology, Mackean, D. G., 2009, pages 2 - 10) for two questions

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Question 1 is compulsory.

1\. a). i) State the views of J. B. Conant on how scientific progress is made. [3]

ii) Explain the relationship between hypothesis formulating and hypothesis testing [4]

b) Explain the advantages of using divergent questions in discovery and inquiry learning. [5]

c) Discuss the place of behavioural objectives in the science classroom. [5]

d) i) Explain how a test specification grid provides important information about the contents of a test. [5]

ii) Briefly, state how teacher feedback from assessment can motivate learners in science classes. [3]

Choose any 3 questions below.

2\. a) i) Peter Medawar 'hates' the scientific paper. Critically examine this statement. [6]

ii) Explain how the views of Holton and Roller coincide with those of Medawar when conducting and reporting scientific research. [4]

b) Compare and contrast the views of Karl Popper and Thomas Kuhn regarding the criterion of demarcation for scientific theories and, therefore, scientific knowledge. [15]

3\. a) Two essential features of inquiry teaching and learning, as suggested by the National Science Education Standards, are

i) *learners are engaged by scientifically oriented questions*
ii) *learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions*

Explain how these features can be developed in the classroom using examples from biology. [6]

b) You are preparing to teach a Form V inquiry lesson on human influences on ecosystems. You may refer to the attachment (Jones, M., 2002)
i) Explain how the lesson could be taught using the following strategies:
a) Questioning, and
b) Group work and cooperative learning [7,7]

ii) For each technique in i) identify the science process skills you would aim to develop. [5]

4. a) Explain the merits of the use of oral interviews and portfolios as forms of assessment in science. **[10]**

   b) Compare and contrast criterion referenced and norm referenced assessment. [5]

   c) Discuss the advantages and disadvantages of using open and closed test items in science tests and examinations. **[10]**

5. a) Given a Form IV biology class of 65 pupils, explain how you would prepare and organise the class for a practical activity on the structure of animal and plant cells in a semi-urban school in Swaziland. You may refer to the attachment (Mackean, D. G.,2009) **[20]**

   b) Identify and explain the science content standards that would be addressed by this activity. [5]

6. a) A Form 2 science teacher noticed that her class did not show as much enthusiasm in her science class as they did in Form 1. In retrospect, she realised that this had been a gradual trend since Form 1.

   i) Discuss three possible causes for the change in the behaviour and responses of the class. **[9]**

   ii) Describe the strategies the teacher should employ to motivate her class. **[9]**

   b) Discuss the consequences of increasing teacher wait-time in science inquiry lessons. [7]

Chapter

Human influences on ecosystems

Human activities may have harmful effects on ecosystems, for example by destroying habitats or polluting air, water or soil. Conservation can help to prevent and reverse such damage.

Food production ▶

Modern technology and agriculture

For thousands of years, people have been growing crops and keeping animals for food. At first, such agriculture was performed on a relatively small scale. As the human population has grown, and as the availability of machinery, fertilisers and pesticides continues to increase, people are able to produce more and more food from a given area of land.

This increase in agricultural production has brought great benefits to many people. In the developing countries of the world, general levels of nutrition have improved considerably in the last 40 years or so. For example, in 1961, the average daily energy intake of a person in a developing country was 8000 kJ. By 1983 this had increased to 10 000 kJ.

Nevertheless, the distribution of this improvement in agricultural technology around the world is very uneven. Figure 15.1 shows that although grain production has increased rapidly in Western Europe, it has not done so in Africa. This is partly because of climatic problems such as lack of water in many parts of Africa, but is also because people do not have enough money to buy the machinery, fertilisers and pesticides which could help them to increase the yields of the crops they grow.

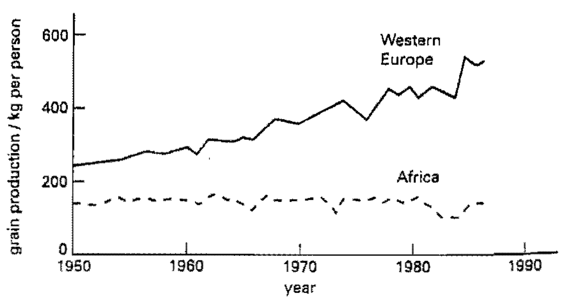
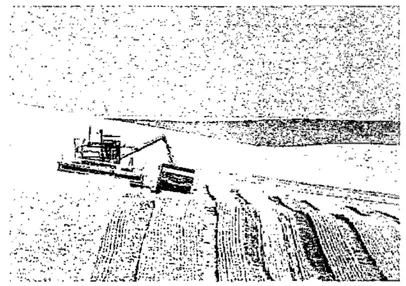


Figure 15.1 ▶
Changes in grain production since 1950 in Western Europe and Africa.



▲ **Figure 15.2**
In the USA, farming is done using sophisticated and powerful machinery. Here, wheat is harvested in California.

▲ **Figure 15.3**
In many parts of Africa, farmers are not able to use much machinery. This means that more people are needed to work the land, and they often have to work very hard. These farmers are ploughing in Ethiopia.

Moreover, although crop production may be increasing, so is the size of the human population. In Africa south of the Sahara, the human population is growing at a faster rate than the crop production. This means that the amount of food produced per person is actually getting less. This problem is not going to be solved simply by improvements in technology. Much of the problem lies in damage being done to the land, which results in soil erosion and loss of fertility.

Soil erosion

Soil is a precious material. A good, deep soil, suitable for growing crops, takes thousands of years to form. If it is lost, it cannot easily be replaced.

When there are plants growing in soil, it is very resistant to erosion. Rain falling onto the ground first hits the plants rather than the soil. The water soaks gently into the soil. A lot of the water is taken up by the plants. However, if all the plant cover has been removed, then the rain drops fall directly on the soil, loosening and moving the soil particles. There are no plants to absorb the water, so a lot of it runs off the land over the surface of the soil, carrying away the soil as it does so.

Country	Soil erosion / metric tonnes per hectare per year
USA	18
Jamaica	36
Nepal	50
Ethiopia	42
India	75

▲ **Table 15.1**
Rates of soil erosion in five countries.

Question

15.1 Use an atlas to find the five countries listed in Table 15.1. For each country, find out its average rainfall (this information should be in your atlas) and how mountainous it is. Use this information to suggest why some of these countries have higher rates of soil erosion than others.

When people clear forests to grow crops, they frequently open up the soil to this kind of erosion. The soil of tropical rainforests is especially thin, and easily eroded. Within a few years of cutting down the trees, the soil will probably be too thin and poor to grow crops.

▲ **Figure 15.4**
Removing trees can quickly lead to devastating soil erosion. Here you can see that, where the trees are growing, the soil has remained. Where they have been cut down, large amounts of soil have been washed away.

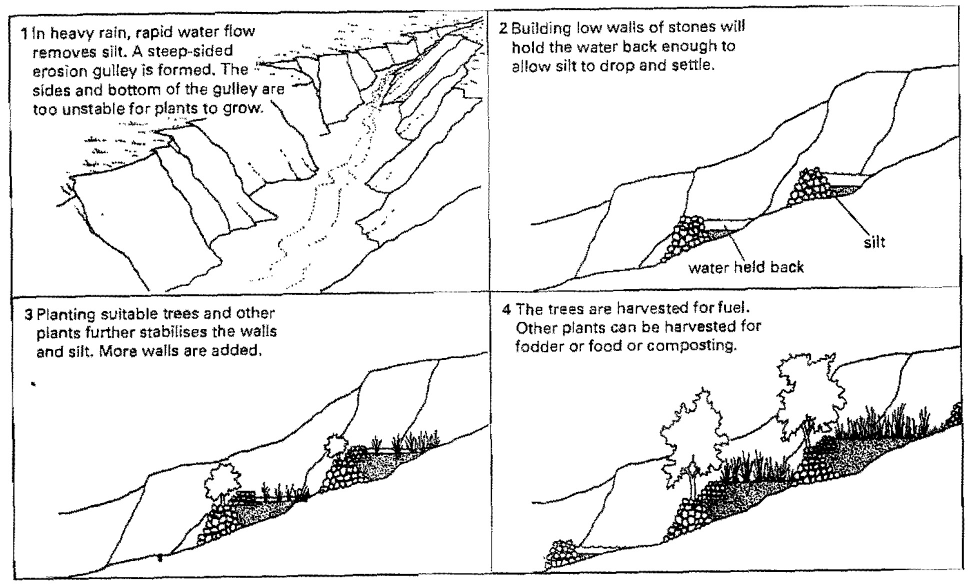
▲ **Figure 15.5**
Clearing forests on slopes allows more rainwater to run into rivers. This can cause flooding.

Another way plant cover can be removed from soil is by **overgrazing**. Animals such as cattle, sheep and goats may increase soil erosion by eating almost all the plants in an area, and trampling the soil.

Even deep, fertile soils are easily eroded. A farmer may leave his fields empty for part of the year. During this time, rainfall can easily wash away the soil.

As well as losing irreplaceable soil, this can cause damage to waterways. The eroded soil is carried into rivers. The rivers may silt up, reducing their navigability, and making use of the water for irrigation more difficult. When it rains heavily, the silted rivers cannot carry away the excess water, and flooding may result.

Reducing soil erosion



▲ **Figure 15.6**
Gulley erosion and reclamation. No expensive technology or materials are needed to stop this type of soil erosion – just stones, and people to carry them.

Figure 15.6 shows how erosion can lead to trenches or **gulleys** being formed in soil, and what can be done about this.

There are many other ways in which people can reduce soil erosion. These include:

- not cutting down trees in areas where the soil is most likely to erode, and planting trees to help to stabilise soil on open land
- not grazing too many animals on land where the soil is vulnerable to erosion
- making terraces where crops are grown on hillsides, so that water cannot wash soil down the slope
- adding humus, such as animal dung and rotted plant material, to the soil, to make it more likely to stick together and less easily washed away
- keeping a cover of plants on the soil, as their roots will help to hold the soil in place.

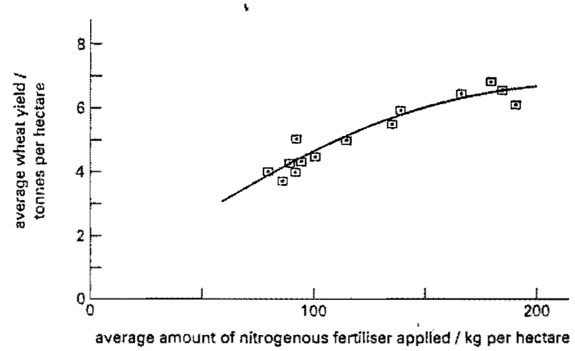
▲ **Figure 15.7**
Farmers on these hillsides in the Philippines have built terraces for growing rice. This stops too much soil being washed down the slope.

However, for people finding it difficult to get enough to eat, there may be little incentive to do any of these things. If your only concern is how to survive until tomorrow, or until next year, it is difficult to worry about what may happen to the soil in ten years' time. Problems of soil erosion in poor areas of developing countries can only be solved by improving people's standards of living, so that they do not need to make such heavy demands on the land.

Problems resulting from over-use of fertilisers

One of the main reasons for the increase in crop production in Western Europe shown in Figure 15.1 (page 258) is the increase in use of nitrogenous fertilisers. Adding fertilisers to the soil can greatly increase crop yields (Figure 15.8). Without fertilisers, there would be no hope of feeding the world's population.

Figure 15.8 ▶ Graph to show the relationship between application of nitrogen fertilisers and wheat yields in the UK, 1965–90.



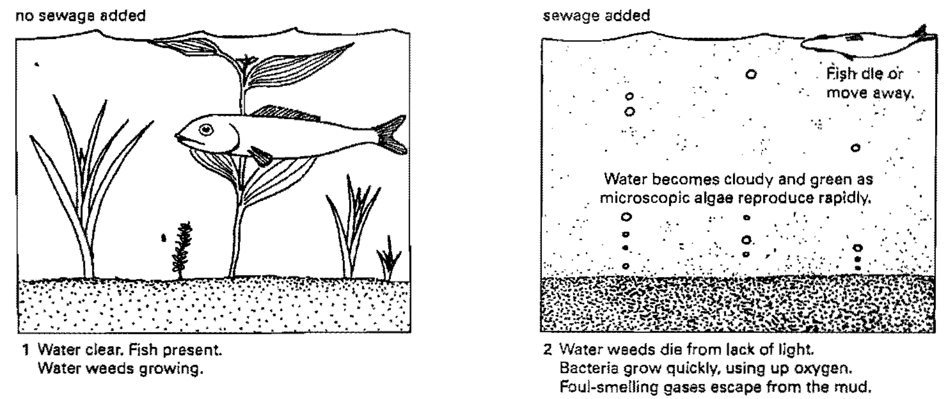
However, careless use of fertilisers can cause great damage to ecosystems. The nitrates contained in fertilisers are very soluble. Any nitrates put onto the soil and not immediately taken up by plants can be washed away when it rains. This is called **leaching**. The leached fertilisers may end up in streams, rivers and lakes.

The fertilisers provide nitrogen for plants and algae, which grow quickly. The algae may grow so much that the water looks thick and green. This blocks out light for the plants growing lower down in the water. These plants, and eventually the algae as well, die. This provides food for bacteria, so the populations of bacteria increase. The bacteria respire, using up oxygen in the water. Animals living in the water cannot breathe, and so they die.

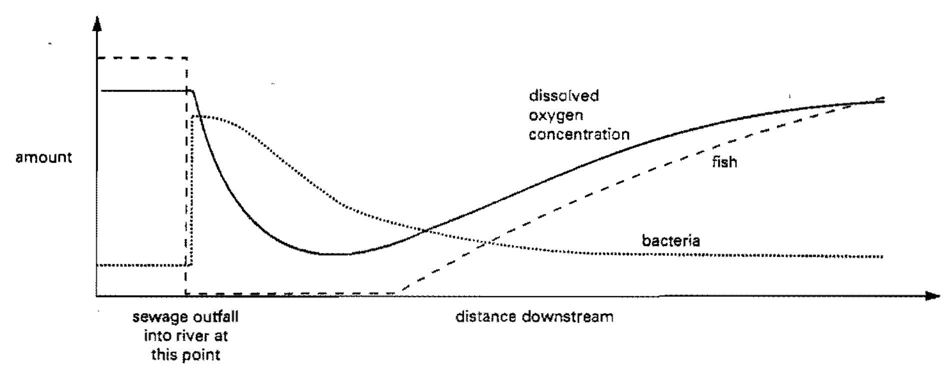
This process is called **eutrophication**. It can happen whenever plant nutrients get into ponds, lakes, rivers or the sea. Fertilisers are not the only cause of eutrophication. Untreated sewage, and waste from factories producing foodstuffs can also cause this problem.

Question

15.2 Figure 15.9(b) shows how the amount of oxygen, numbers of bacteria and numbers of fish change as you go downstream from an outfall of untreated sewage. Suggest explanations for the shapes of each of these three curves.



(a) Eutrophication.



(b) Changes in dissolved oxygen, bacteria and fish, upstream and downstream of an outfall of untreated sewage.

▲ Figure 15.9

Preventing problems from over-use of fertilisers

To prevent these problems, people should:

- only apply fertilisers to land when plants are growing, so that they will immediately be taken up
- not apply too much fertiliser, so that it will all be taken up by plants
- not apply fertiliser when it is about to rain
- where possible, use manure or other organic fertilisers instead of fertilisers such as ammonium nitrate – manure is often cheaper, it breaks down slowly and releases the nitrogen to the plants over a long period of time, and adds humus to the soil, which can improve its texture and reduce erosion.

Pollution ▶ **Pollution** can be defined as *the addition of something to an ecosystem which can damage the living organisms within it.*

Water pollution

The effects of water pollution by **fertilisers** have just been described. Pollution by untreated **sewage** has a similar effect, causing eutrophication.

Pollution by sewage causes another problem, too. Sewage is waste water from houses and industries. It contains human urine and faeces, which may be contaminated with harmful viruses and bacteria. Many diseases, such as cholera, typhoid and poliomyelitis, can be transmitted in untreated sewage. A person may catch these diseases by swimming in or drinking contaminated water, or eating food that has come into contact with it.

Supplement

Sewage treatment

Figure 15.10 outlines how sewage may be treated to make it safe. After treatment, the effluent can be allowed to flow into a river, where it will not cause eutrophication, nor carry the risk of disease.

There are many different methods of sewage treatment, but all of them rely on microorganisms, such as

Supplement

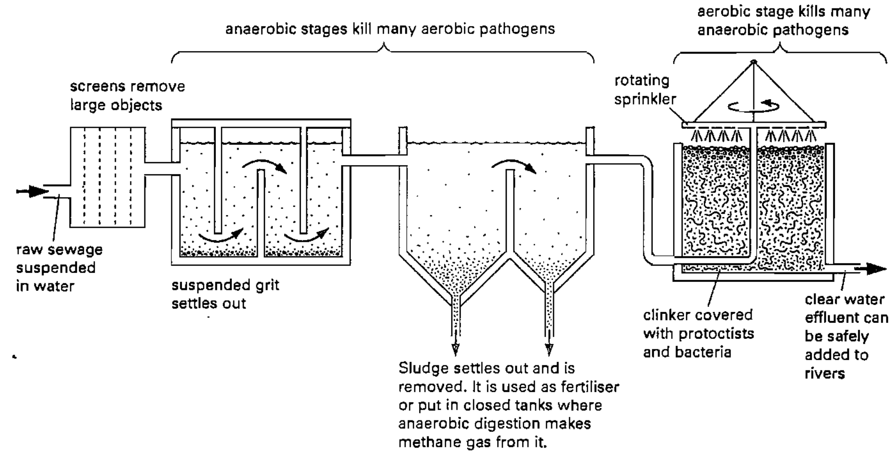


Figure 15.10
One method of sewage treatment.

bacteria and **protoctists**, to feed on the sewage. The microorganisms break down harmful substances in the sewage. In the example shown in Figure 15.10, this is partly done in **anaerobic**, or oxygen-free, conditions. This method has the advantage of producing methane, which can be used as a fuel.

Water pollution by inorganic waste

Inorganic substances are substances that have not been made by living things. They tend not to contain carbon in their molecules. One example is ammonium nitrate, which is widely used as a fertiliser. The effect of pollution by fertilisers has been described in this chapter.

Another important inorganic water pollutant is **mercury**. Mercury may get into water as a waste product from factories. It is highly toxic.

For example, in the 1950s a disease broke out in a Japanese fishing village. Some people died, others suffered from problems with their muscles and nervous systems, and many deformed babies were born. The problem was tracked down to mercury, which had got into the sea near the village from a factory making plastics. The factory was using mercuric sulphate as a catalyst. The mercury was getting into the bodies of fish, and then into people who ate the fish. Once the factory's discharge of waste into the sea was stopped, the disease disappeared.

Air pollution

We have already described, on page 247, how the burning of fossil fuels releases **carbon dioxide** into the atmosphere. Another gas produced when fossil fuels, especially coal, are burnt is **sulphur dioxide**. Most sulphur dioxide pollution is caused by coal-burning industries, such as power stations.

Sulphur dioxide is a very unpleasant gas. It is an **irritant**, which means that it causes discomfort when you breathe it in. In people who have a tendency towards bronchitis or asthma, it can trigger an attack. Sulphur dioxide gas can also get into plants, through the stomata in their leaves. It can kill cells in the leaf, eventually killing the whole plant if the pollution continues.

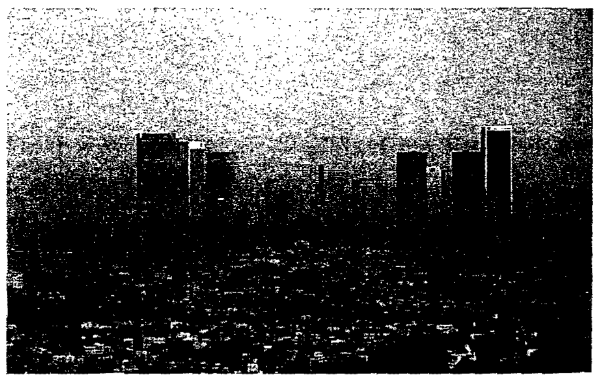


Figure 15.11 ▶
Sulphur dioxide pollution in Los Angeles comes from the huge number of cars which are used in the city.

Supplement

Acid rain

Sulphur dioxide, SO_2, in the atmosphere may be oxidised to sulphur trioxide, SO_3. The sulphur trioxide dissolves in water in the atmosphere to form sulphuric acid, which falls as acid rain or acid snow.

Sulphur dioxide is not the only gas that causes acid rain. **Nitrogen oxides** also do this. The major source of nitrogen oxides is car exhaust fumes. Figure 15.12 shows the formation and effects of acid rain.

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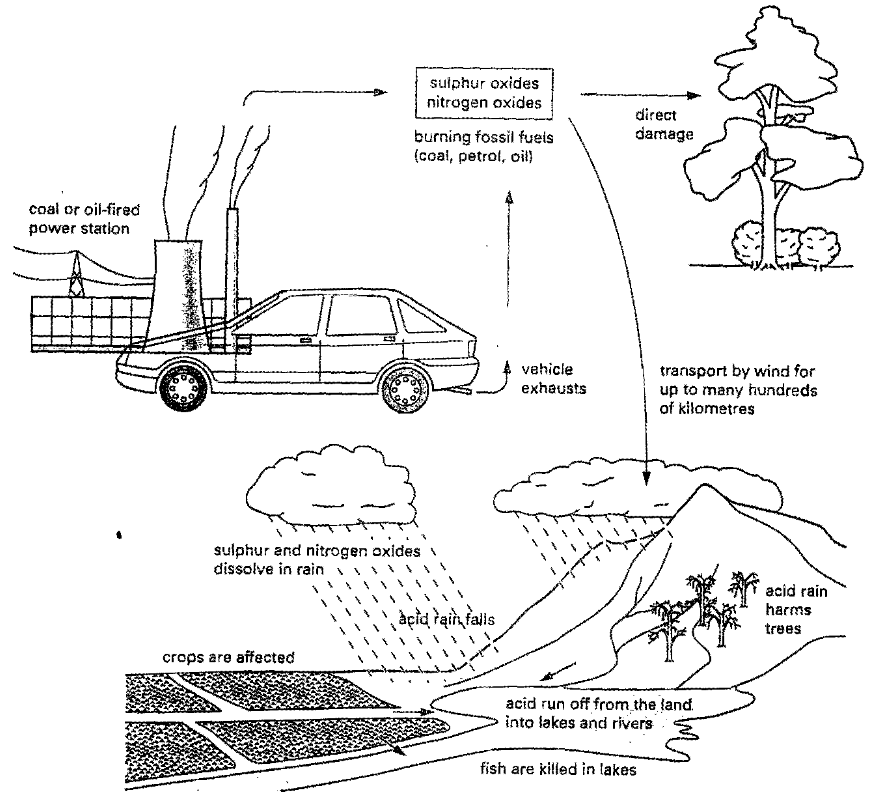


Figure 15.12
Acid rain.

Acid rain may damage the leaves of trees directly, but these effects are relatively small. More importantly, it can dissolve and wash away important minerals, such as calcium and magnesium, as it soaks through the soil. On thin soils, such as those on mountainous areas of some parts of Europe (Figure 15.13 overpage), this can make the soil so poor that whole forests die.

The acid rain also washes out aluminium ions from the soil. The aluminium accumulates in rivers and lakes. Aluminium ions are toxic to fish, especially young ones, as they can stop the gills functioning properly. The fish in badly acidified lakes are often killed.

Figure 15.13
Areas of Western Europe most affected by acid rain.

Acid rain can damage buildings. Some buildings are made of stone containing carbonates, such as calcium carbonate (limestone). The acid dissolves the carbonate, causing the stone to crumble away.

Reducing pollution from acid rain

Several steps are being taken in developed countries to reduce pollution by sulphur dioxide and nitrogen oxides. These include:

- Installing 'scrubbers' which remove almost all of the sulphur dioxide from the waste gases at coal-burning power stations. However, this is expensive, and means that the electricity produced by these power stations costs more.
- Using catalytic converters on car exhausts. These convert the nitrogen oxides into nitrogen. (However, although catalytic converters help reduce acid rain, they do nothing to reduce the amount of carbon dioxide emitted in the exhaust fumes.)

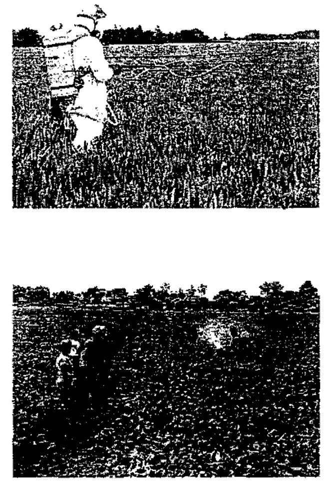
Pollution by pesticides and herbicides

Pesticides are chemicals used to kill pests, such as insects that eat crop plants. Herbicides are chemicals used to kill weeds.

Benefits of using pesticides Pesticides are used to reduce crop losses, and also to control the spread of diseases like malaria, which are spread by insect vectors.

Pesticides have been immensely valuable in increasing food production. In developing countries, it is estimated that at least a third of the crops grown are lost to pests. For cotton production, the figures are even worse – it has been calculated that, without the use of pesticides, almost half of the cotton produced in developing countries would be destroyed.

Pesticides also help to control diseases. Malaria is a devastating disease, which causes repeated and debilitating illness, and may kill. Without pesticides to control mosquitoes, many more people worldwide would suffer from malaria. A campaign run by the World Health Organisation since 1955, using pesticides



▲ **Figure 15.14**
The amount of care taken over the use of pesticides in developed and some developing countries differs greatly. The first picture shows wheat being sprayed near Oxford, England, while in the second one a farmer sprays cotton plants with DDT in Nicaragua. What differences can you see in the way the pesticide is being used? What problems might the Nicaraguan farmer be causing?

and other methods to control mosquitoes and hence malaria, is estimated to have saved 15 million lives.

Problems with using pesticides Despite their benefits, pesticides must be used with great care. In the past, before the problems associated with pesticides were understood, a lot of damage was done to the environment.

For example, one of the first insecticides to be used was **DDT**. This was widely used in the 1950s and 1960s. However, it was discovered that DDT used to kill insects could enter food chains. It is a **persistent** pesticide – it does not break down, but remains in the environment. As it was passed along a food chain, it became more and more concentrated in each successive organism. Carnivores ended up with so much DDT in their bodies that they died. DDT has now been banned in most countries.

Persistent pesticides may end up in food intended for humans, as **pesticide residues**. This is particularly likely if food is harvested soon after it has been sprayed with pesticides. In most developed countries, there are strict regulations about how long food must be left between spraying and harvesting, but some developing countries do not follow these rules. Thus, people could be poisoned by eating food containing pesticide residues.

People using the pesticides can also be poisoned if they do not wear proper protective clothing. Many pesticides can be absorbed through the skin. In Britain, some farmers have become ill after using pesticides called organophosphates, to kill parasites on sheep.

Another problem is that insects and weeds may develop **resistance** to pesticides. This happens in a similar way to the development of resistance to antibiotics by bacteria, described on pages 229–230. This has happened, for example, with mosquitoes, which have built up resistance to the pesticides used to kill them. Mosquitoes, and the malaria they carry, are beginning to spread back into areas where they had been eradicated.

Insecticides (pesticides used to kill insects) often kill not only harmful insects, but also helpful ones. Such insecticides are said to be **non-specific**. Thus, a farmer spraying a crop with a pesticide to kill a pest may also kill all the natural predators, such as spiders, of that pest. In future, if he does not keep on spraying with the pesticide, he will have an even worse problem with the pests than before.

How can all these problems be solved? Much more care is now taken when new pesticides are developed, to make sure that they are not persistent. However, it is now realised that it is in everyone's interest to find other ways of controlling pests. This may involve **biological control**, in which a natural predator of a pest is used to keep the pest's population low. This has the advantages that it is often cheaper, does not cause pollution, and only kills the pest and not other living organisms.

Question

15.3 The table shows the increase in use of pesticides on cotton crops in an area of Sudan between 1959 and 1979.

Year	Average number of times pesticide was sprayed in one year
1959	1.0
1964	2.5
1969	4.9
1974	6.0
1976	6.5
1977	8.1
1978	9.3

a Plot a graph to show these data. Take care with the *x*-axis!

b Describe what happened to the use of pesticides between 1959 and 1978.

c Suggest reasons for the changes you have described.

d Suggest what the cotton farmers of Sudan might have done to allow them to decrease their use of pesticides.

Pollution by nuclear fallout

Ionising radiation, such as alpha, beta and gamma radiation, damages DNA. This can lead to cancer or birth defects. Exposure to large amounts of radiation can also cause radiation sickness, when so many cells are damaged that the person becomes very ill, and may die.

There is ionising radiation all around, all the time. This is called **background radiation**, and it comes from rocks in the Earth, and from cosmic rays from the Sun. However, in most parts of the world, this background radiation is not great enough to cause any harm.

Nuclear reactions can produce large amounts of radiation. Nuclear reactions take place in nuclear power stations. If these are well designed, well built and well maintained, little or no radiation leaks from them. However, when accidents occur, such as at Chernobyl, large amounts of radioactive substances, emitting ionising radiation, can be released into the air. This is sometimes called nuclear fallout. Nuclear bombs also produce enormous quantities of nuclear fallout.

Some of the radioactive substances produced last for a very long time, and may be carried in the air over very large distances. In the Chernobyl accident, a radioactive form of iodine was produced, which fell to the ground in many countries, including Wales. The radioactive iodine was absorbed by grass, and eaten by sheep. Many years after the accident, it is still not safe to eat sheep which have grazed in some of these areas, because levels of radiation are still high.

Supplement

Pollution by non-biodegradable plastics

Substances such as sewage are **biodegradable**. Given time, bacteria and other microorganisms will break them down. Biodegradable substances cause only short-term pollution problems.

In the past, most of the waste substances produced by humans were biodegradable. However, many substances used in the manufacturing industry, such as metals, glass and plastics, are not biodegradable. If these materials are thrown away, they remain in the environment virtually for ever. They are an eyesore, and can be dangerous to small animals which may get trapped in them.

Disposal of non-biodegradable plastics is a problem. They can be buried, but they then remain in the soil for years. They can be burnt, but many of them release toxic gases.

Some plastics can be **recycled**. The plastic called PET, which is used for making bottles for soft drinks, can be reused. People save their empty PET bottles and take them to a collection point, from where they are taken to a recycling plant to be made into new plastic articles. This reduces plastic pollution. It would be better still if the bottles were cleaned and reused as they are, but this is expensive and difficult to do.

Question

15.4 One way of disposing of non-biodegradable plastics is to burn them in order to produce energy. The table shows the amount of energy released when 1 kg of different kinds of plastics are burnt.

Plastic	Energy released on combustion / kJ per kg
Polystyrene	38 000
Polyethylene	43 000
PVC	22 000
PET	22 000
Mixed plastic	37 000

a State one problem encountered when burning plastics.

b Suggest a use that could be made of the energy released from burning plastic waste.

c Suggest why sorting plastic waste before burning it could be useful.

d Assuming that all of these plastics could be recycled, and using only the information in the table, suggest which plastics would be better recycled than used as a fuel.

Conservation ▶

Conserving natural resources

Humans take and use a great many materials from the Earth. These are called **resources**. We shall consider just three examples – fossil fuels, water and trees used for paper.

Fossil fuels were produced millions of years ago. They are only forming very slowly, in just a few tiny areas, now. As we use up the fossil fuels in the Earth, they are not renewed. They are ***non-renewable resources***.

Huge amounts of fossil fuels are being used all over the world, especially in developed countries, to provide energy. This causes several problems. Two such problems are:

- Burning fossil fuels causes pollution by carbon dioxide, sulphur dioxide and nitrogen oxides.
- Our supply of fossil fuels will soon run out.

Although some attempts have been made by some countries to cut down their energy consumption, and hence their rate of use of fossil fuels, there has been little success in this. Instead, we are beginning to turn to using **renewable resources** for energy production. These include solar power, wave and tidal power, hydroelectric power and wind power. By using these resources for generating electricity, we can not only reduce our rate of use of fossil fuels and ensure that we have energy supplies in the future, but can also reduce pollution.

Water is a vital substance which is in short supply in many countries. Although there is plenty of water on Earth to provide every person with more than enough for their needs, the distribution of water is very uneven. Thus, in parts of the world where population is very dense, or where rainfall is very low, water may be a resource that needs to be **conserved**.

Trees are used for many purposes, and the problems caused by deforestation have been described earlier. Many trees are cut down to produce **paper**.

Conservation of species and their environments

The impact of human activities on the environment, such as deforestation, farming and pollution, has caused

▲ **Figure 15.15**
When old forest trees are cut down, lasting damage is done, because it takes so long for such trees to be replaced. The environment is likely to be permanently damaged, destroying habitats for many different species of living organisms.

tremendous changes to the habitats of many organisms. This can destroy some species completely, making them extinct. Figure 15.16 shows some causes of threats to mammals and birds.

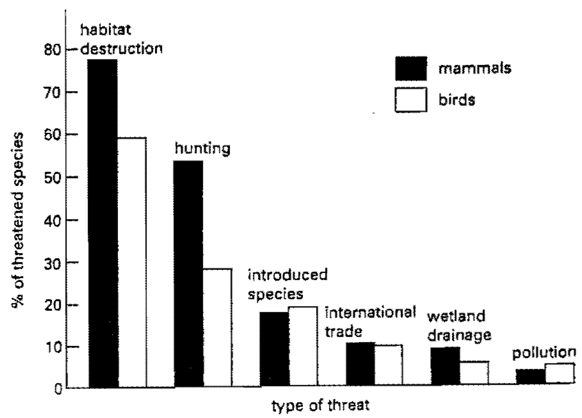
For example, the cutting down of tropical rainforest puts large numbers of species in danger of extinction. One hectare of tropical rainforest may contain 200 different species of trees, and thousands of species of other plants and animals. Many of these species have very small ranges, so that cutting down quite a small piece of forest may remove almost all of their habitat. It is very easy to make such a species extinct.

This is not a problem that has just begun to happen. Humans have been causing extinctions for a very long time. For example, it is thought that the first humans settled on the Pacific islands of Fiji, Tonga and Samoa about 3000 years ago. Their coming caused mass extinctions of animals living on the islands. Of the 25 species of flightless birds that lived there, only 8 survive today.

Similarly, Hawaii has suffered great losses of bird species. When European settlers first arrived there in 1778, there were 50 species of birds living there. Now there are only 34.

Why does it matter if a species becomes extinct? For many people, there is no question about this – it is obvious that the loss of a species is a loss to the whole

Figure 15.16 ▶
The relative importance of six types of environmental threat to mammals and birds.



world. The fewer species there are on Earth, the less diverse and rich is our environment.

There are other arguments, too, directly related to the potential benefits to humans of conserving as many species as possible. The more different species there are in an ecosystem, the more stable the ecosystem is. This means that any changes which take place – such as a new disease evolving, or a climatic disaster – have less chance of causing lasting damage to the ecosystem than if only a few species live in it. Complex, rich ecosystems, with many different species living in them, help to stabilise the environment, making it more able to support not only the species that live in it but also humans as well. Rich ecosystems mean a healthy Earth.

You may be surprised to know that large numbers of new species are discovered each year. We still do not know all the different kinds of living things on the Earth. In 1993, the number of known species was about 1.4 million. Some biologists estimate that this is only one tenth of the number of species which live on Earth! Of course, these as yet undiscovered species will not be large animals, but mostly small ones such as insects (especially beetles), and small plants. When we destroy part of a tropical rainforest, we may be destroying many totally unknown species, for ever.

Some of these species may be directly useful to humans. For example, one small plant that comes from Madagascar, called the rosy periwinkle, was recently discovered to contain a chemical which can help to cure cancer. The use of this plant has saved the lives of hundreds of children suffering from leukemia. How many other useful, unknown, species exist?

Much can be done to reduce the likelihood of extinctions. The main focus must be on conservation of whole ecosystems. This means reducing the impact humans have on areas which are especially important for wildlife, such as tropical forests. However, this is not easy. Many of the countries in which tropical rainforests still grow are relatively poor. By cutting down their forests, people can temporarily increase their standard of living, by selling timber from the forest, or by increasing the amount of agricultural land. Such countries need help from richer ones, in order to be able to afford conservation measures. The developed countries must not forget that they have already destroyed many of their natural habitats.

Question

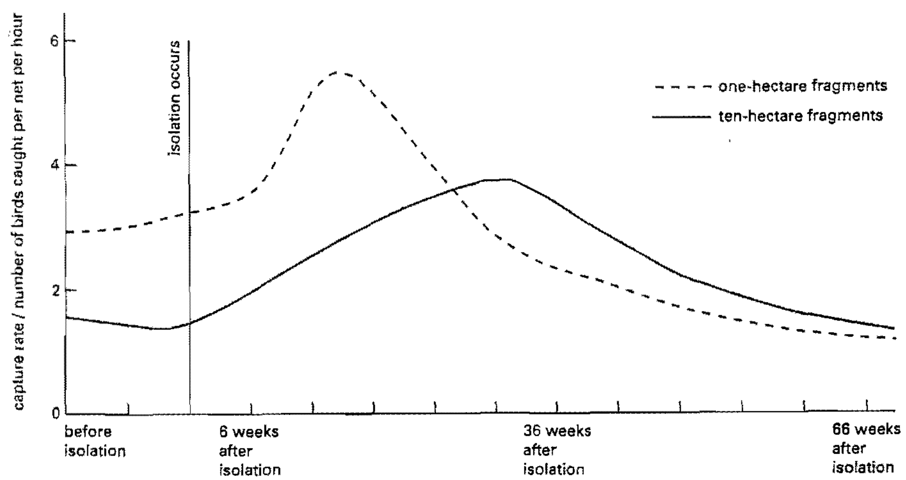
15.5 One strategy used to attempt to conserve species is to preserve areas of their habitat.

For example, as rainforest in one part of the Amazon basin was destroyed, areas of different sizes were left as undisturbed habitat. Biologists counted the number of species of birds in these areas before and after the removal of the rainforest around them. They did this in areas of two different sizes, one hectare and ten hectares. The results are shown in Figure 15.17.

a Suggest why the number of bird species caught in the area increased in the few weeks after the surrounding forest was cut down compared with before.

b Suggest why the number of bird species caught in the area gradually decreased to below the original levels.

c What do these results suggest about the usefulness of such isolated patches of undisturbed habitat as wildlife reserves?



▲ **Figure 15.17**
The numbers of birds caught before and after isolation of fragments of forest.

Supplement

Recycling

One way of conserving water is to reuse or recycle it. Water that has been used for washing, or in industry, or for any other purpose, can be treated to make it suitable for reuse. This can also apply to water that has been drunk! It is excreted from the body in urine, which can be treated in sewage plants to destroy any harmful organisms and produce a harmless effluent. The water will need further treatment before it is pure enough to drink.

We can reduce the number of trees that are cut down by recycling paper. Newspapers, magazines and cardboard wrapping can be collected and taken to recycling plants. Here, the print on the paper is removed using chemicals, and the paper mixed with water to make a slurry before being re-rolled into sheets. Recycled paper is not as pure white as 'first-time round' paper, nor can it be of such a fine texture. However, it is very suitable for making paper towels, paper bags, writing paper and packaging.

It should be realised, however, that in many parts of the world the trees cut down to make paper have been specially planted just for this purpose. When they are harvested, new trees are planted to take their place. Paper-making does most harm to the environment when the trees used are taken from mature forests, such as tropical rainforests, which are irreplaceable.

- Modern technology has greatly increased the output from farming. However, this technology is not always available to farmers in developing countries.
- Deforestation and overgrazing can cause soil erosion, which in turn can lead to flooding.
- Water pollution by fertilisers or untreated sewage can cause bacterial populations to increase rapidly. The bacteria use up oxygen in the water, so that animals such as fish cannot live there. This is called eutrophication.
- Sulphur dioxide is produced when coal or oil are burned. It combines with oxygen and water in the air to form acids, which fall as acid rain. This can damage trees and aquatic organisms.
- Nuclear fallout of radioactive substances can increase the likelihood of mutations occurring.
- Non-biodegradable substances, such as plastics, can cause pollution and may harm animals.
- Pesticides and herbicides that are not biodegradable can build up as they pass along a food chain, so that animals feeding at the end of the chain absorb large amounts of them and may be harmed.
- Conservation aims to maintain biodiversity and conserve natural resources. Recyling, for example of paper or water (sewage treatment) can reduce our use of natural resources and reduce pollution.

Cells and tissues

Cell structure
How tissues are studied to see cells: taking sections. Cell components. Plant cells.
Cell division and cell specialization
Cell division and growth. Specialization of cells for different functions.

Tissues and organs
Definitions and examples of tissues, organs and systems.
Practical work
Preparing, observing and drawing plant and animal cells.

Cell structure

If a very thin slice of a plant stem is cut and studied under a microscope, it can be seen that the stem consists of thousands of tiny, box-like structures. These structures are called **cells**. Figure 1.1 is a thin slice taken from the tip of a plant shoot and photographed through a microscope. Photographs like this are called **photomicrographs**. The one in Figure 1.1 is 60 times larger than life, so a cell which appears to be 2 mm long in the picture is only 0.03 mm long in life.

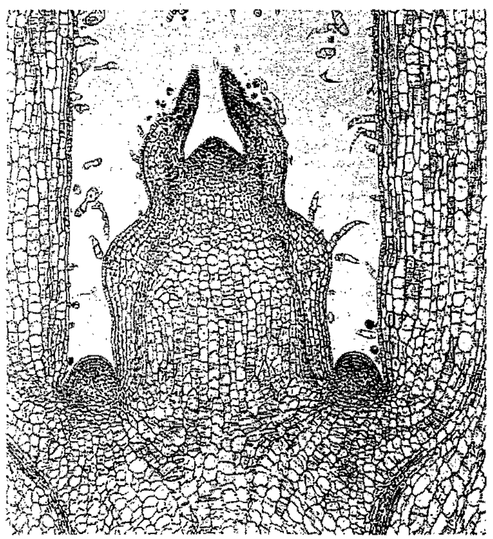


Figure 1.1 Longitudinal section through the tip of a plant shoot (× 60). The slice is only one cell thick, so light can pass through it and allow the cells to be seen clearly

Thin slices of this kind are called **sections**. If you cut *along the length* of the structure, you are taking a **longitudinal section** (Figure 1.2b). Figure 1.1 shows a longitudinal section, which passes through two small developing leaves near the tip of the shoot, and two larger leaves below them. The leaves, buds and stem are all made up of cells. If you cut *across* the structure, you make a **transverse section** (Figure 1.2a).

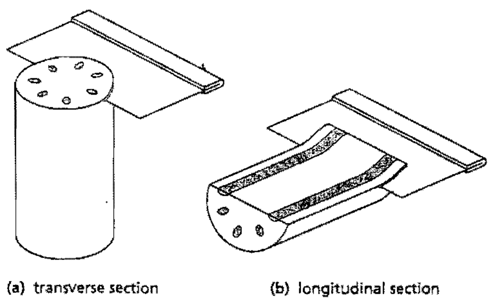


Figure 1.2 Cutting sections of a plant stem

It is fairly easy to cut sections through plant structures just by using a razor blade. To cut sections of animal structures is more difficult because they are mostly soft and flexible. Pieces of skin, muscle or liver, for example, first have to be soaked in melted wax. When the wax goes solid it is then possible to cut thin sections. The wax is dissolved away after making the section.

When sections of animal structures are examined under the microscope, they, too, are seen to be made up of cells but they are much smaller than plant cells and need to be magnified more. The photomicrograph of kidney tissue in Figure 1.3 has been magnified 700 times to show the cells clearly. The sections are often treated with dyes, called 'stains', in order to show up the structures inside the cells more clearly.

Making sections is not the only way to study cells. Thin strips of plant tissue, only one cell thick, can be pulled off stems or leaves (Experiment 1, p. 9). Plant or animal tissue can be squashed or smeared on a microscope slide (Experiment 2, p. 10) or treated with chemicals to separate the cells before studying them.

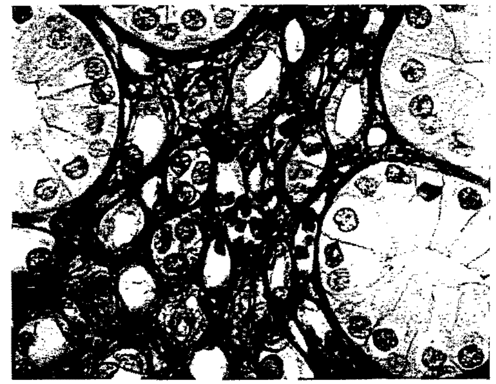


Figure 1.3 Transverse section through a kidney tubule (× 700). A section through a tube will look like a ring (see Figure 1.12b on p. 7). In this case, each 'ring' consists of about 12 cells

There is no such thing as a typical plant or animal cell because cells vary a great deal in their size and shape depending on their function. Nevertheless, it is possible to make a drawing like Figure 1.4 to show features which are present in most cells. *All cells* have a **cell membrane**, which is a thin boundary enclosing the **cytoplasm**. Most cells have a **nucleus**.

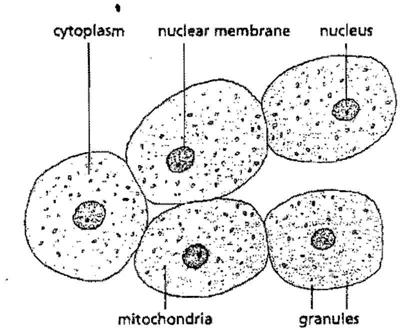


Figure 1.4 A group of liver cells. These cells have all the characteristics of animal cells

Cytoplasm

Under the ordinary microscope (light microscope), cytoplasm looks like a thick liquid with particles in it. In plant cells it may be seen to be flowing about. The particles may be food reserves such as oil droplets or granules of starch. Other particles are structures which have particular functions in the cytoplasm. These structures are the **organelles**. Examples are the **ribosomes**, which build up the cell's proteins (see p. 11) and the **mitochondria**, which generate energy for the cell's living processes (see p. 20).

When studied at much higher magnifications with the **electron microscope**, the cytoplasm no longer looks like a structureless jelly but appears to be organized into a complex system of membranes and vacuoles.

In the cytoplasm, a great many chemical reactions are taking place which keep the cell alive by providing energy and making substances that the cell needs (see pp. 11 and 20).

The liquid part of cytoplasm is about 90 per cent water with molecules of salts and sugars dissolved in it. Suspended in this solution there are larger molecules of fats (lipids) and proteins (see pp. 11–12). Lipids and proteins may be used to build up the cell structures, e.g. the membranes. Some of the proteins are **enzymes** (p. 14). Enzymes control the rate and type of chemical reactions which take place in the cells. Some enzymes are attached to the membrane systems of the cell, whereas others float freely in the liquid part of the cytoplasm.

Cell membrane

This is a thin layer of cytoplasm round the outside of the cell. It stops the cell contents from escaping and also controls the substances which are allowed to enter and leave the cell. In general, oxygen, food and water are allowed to enter; waste products are allowed to leave and harmful substances are kept out. In this way the cell membrane maintains the structure and chemical reactions of the cytoplasm.

Nucleus (plural = nuclei)

Most cells contain one nucleus, which is usually seen as a rounded structure enclosed in a membrane and embedded in the cytoplasm. In drawings of cells, the nucleus may be shown darker than the cytoplasm because, in prepared sections, it takes up certain stains more strongly than the cytoplasm. The function of the nucleus is to control the type and quantity of enzymes produced by the cytoplasm. In this way it regulates the chemical changes which take place in the cell. As a result, the nucleus determines what the cell will be, e.g. a blood cell, a liver cell, a muscle cell or a nerve cell.

The nucleus also controls cell division as shown in Figure 1.8 on p. 5. A cell without a nucleus cannot reproduce. Inside the nucleus are thread-like structures called **chromosomes**, which can be seen most easily at the time when the cell is dividing. (See p. 182 for a fuller account of chromosomes.)

Mitochondria

The mitochondria are tiny organelles present in plant and animal cells. They may be spherical, rod-like or elongated. They are most numerous in regions of rapid chemical activity and are responsible for producing energy from food substances (see 'Respiration', p. 19).

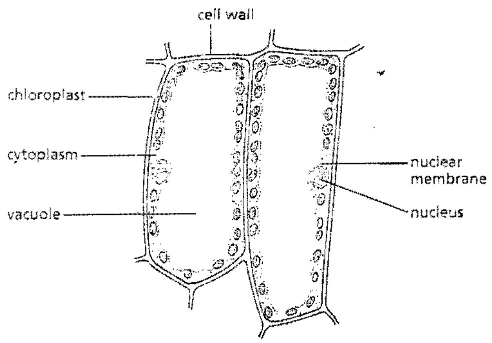


Figure 1.5 Palisade cells from a leaf

Plant cells

A few generalized animal cells are represented by Figure 1.4, while Figure 1.5 is a drawing of two palisade cells from a plant leaf (see pp. 51 and 53).

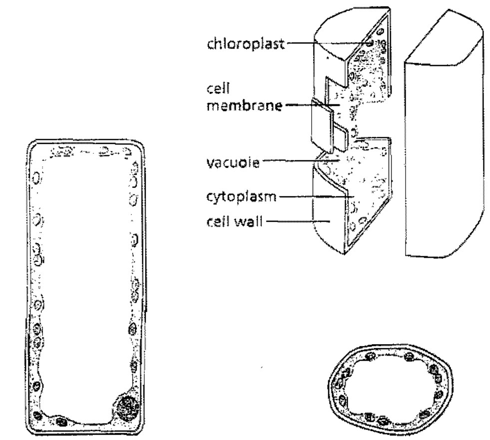
Plant cells differ from animal cells in several ways:

1 Outside the cell membrane they all have a **cell wall** which contains cellulose and other compounds. It is non-living and allows water and dissolved substances to pass through. The cell wall is not selective like the cell membrane. (Note that plant cells *do* have a cell membrane but it is not easy to see or draw because it is pressed against the inside of the cell wall. See Figure 1.6.)

Under the microscope, plant cells are quite distinct and easy to see because of their cell walls. In Figure 1.1 it is only the cell walls (and in some cases the nuclei) which can be seen. Each plant cell has its own cell wall but the boundary between two cells side by side does not usually show up clearly. Cells next to each other therefore appear to be sharing the same cell wall.

2 Most mature plant cells have a large, fluid-filled space called a **vacuole**. The vacuole contains **cell sap**, a watery solution of sugars, salts and sometimes pigments. This large, central vacuole pushes the cytoplasm aside so that it forms just a thin lining inside the cell wall. It is the outward pressure of the vacuole on the cytoplasm and cell wall which makes plant cells and their tissues firm (see p. 30). Animal cells may sometimes have small vacuoles in their cytoplasm but they are usually produced to do a particular job and are not permanent.

3 In the cytoplasm of plant cells are many organelles called **plastids** which are not present in animal cells. If they contain the green substance **chlorophyll**, the organelles are called **chloroplasts** (see p.38). Colourless plastids usually contain starch, which is used as a food store.



(a) longitudinal section (b) transverse section

Figure 1.6 Structure of a palisade cell. It is important to remember that, although cells look flat in sections or in thin strips of tissue, they are in fact three-dimensional and may seem to have different shapes according to the direction in which the section is cut. If the cell is cut across it will look like (b); if cut longitudinally it will look like (a)

The shape of a cell when seen in a transverse section may be quite different when the same cell is seen in a longitudinal section and Figure 1.6 shows why this is so. Figures 6.10b and 6.10c on p.55 show the appearance of cells in a stem vein as seen in transverse and longitudinal section.

Questions

1 a What structures are usually present in all cells, whether they are from an animal or from a plant?
b What structures are present in plant cells but not in animal cells?

2 What cell structure is largely responsible for controlling the entry and exit of substances into or out of the cell?

3 In what way does the red blood cell shown in Figure 12.1 on p.108 differ from most other animal cells?

4 How does a cell membrane differ from a cell wall?

5 Why does the cell shown in Figure 1.6b appear to have no nucleus?

6 a In order to see cells clearly in a section of plant tissue, would you have to magnify the tissue
(i) ×5,
(ii) ×10,
(iii) ×100 or
(iv) ×1000?
b What is the approximate width (in mm) of one of the largest cells in Figure 1.3?

7 In Figure 1.3, the cell membranes are not always clear. Why is it still possible to decide roughly how many cells there are in each tubule section?

Cell division and cell specialization

Cell division

When plants and animals grow, their cells increase in number by dividing. Typical growing regions are the ends of bones, layers of cells in the skin, root tips and buds (Figure 1.10). Each cell divides to produce two daughter cells. Both daughter cells may divide again, but usually one of the cells grows and changes its shape and structure and becomes adapted to do one particular job – in other words, it becomes **specialized** (Figure 1.7). At the same time it loses its ability to divide any more. The other cell is still able to divide and so continue the growth of the tissue. **Growth** is, therefore, the result of cell division, followed by cell enlargement and, in many cases, cell specialization.

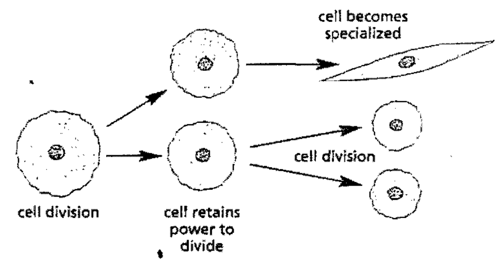


Figure 1.7 Cell division and specialization. Cells which retain the ability to divide are sometimes called **stem cells**

The process of cell division in an animal cell is shown in Figure 1.8. The events in a plant cell are shown in Figures 1.9 and 1.10. Because of the cell wall, the cytoplasm cannot simply pinch off in the middle, and a new wall has to be laid down between the two daughter cells. Also a new vacuole has to form.

Organelles such as mitochondria and chloroplasts are able to divide and are shared more or less equally between the daughter cells at cell division.

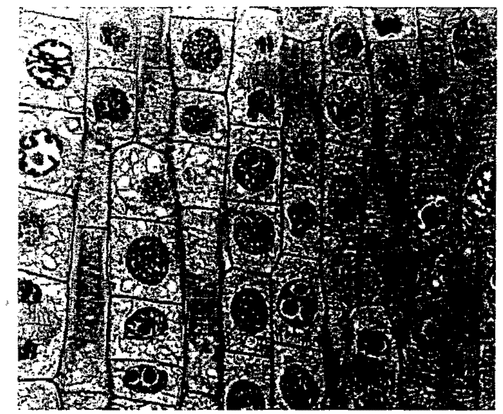
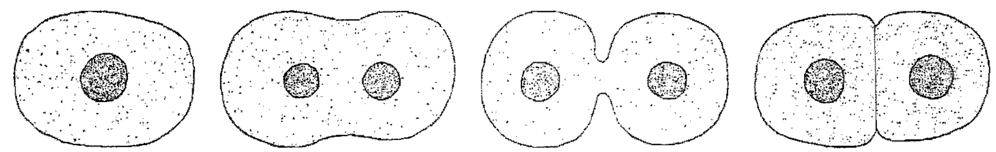
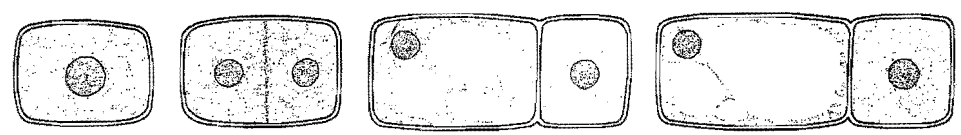


Figure 1.10 Cell division in an onion root tip (× 300). The nuclei are stained blue. Most of the cells have just completed cell division



(a) Animal cell about to divide. (b) The nucleus divides first. (c) The daughter nuclei separate and the cytoplasm pinches off between the nuclei. (d) Two cells are formed – one may keep the ability to divide, and the other may become specialized.

Figure 1.8 Cell division in an animal cell



(a) A plant cell about to divide has a large nucleus and no vacuole. (b) The nucleus divides first. A new cell wall develops and separates the two cells. (c) The cytoplasm adds layers of cellulose on each side of the new cell wall. Vacuoles form in the cytoplasm of one cell. (d) The vacuoles join up to form one vacuole. This takes in water and makes the cell bigger. The other cell will divide again.

Figure 1.9 Cell division in a plant cell

Specialization of cells

Most cells, when they have finished dividing and growing, become specialized (Figure 1.11). This means that:

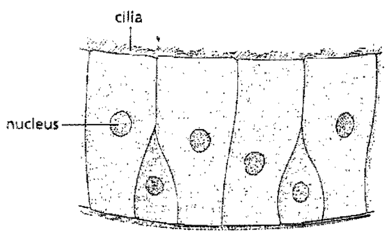
- They do one particular job.
- They develop a distinct shape.
- Special kinds of chemical change take place in their cytoplasm. The changes in shape and chemical reactions enable the cell to carry out its special function. Nerve cells and guard cells are examples of specialized cells.

Nerve cells (Figure 1.11e):

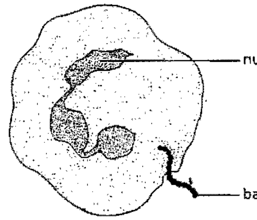
- Conduct electrical impulses to and from the brain.
- Some of them are very long and connect distant parts of the body to the spinal cord and brain.
- Their chemical reactions cause the impulses to travel along the fibre.

Root hair cells (Figure 1.11d):

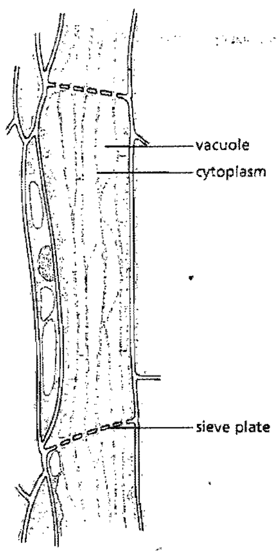
- Absorb water and mineral salts from the soil.
- The hair-like projection penetrates between the soil particles and offers a large absorbing surface.
- The cell membrane is able to control which dissolved substances enter the cell.



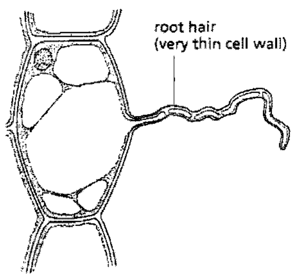
(a) ciliated cells
These form the lining of the nose and windpipe, and the tiny cytoplasmic 'hairs', called cilia, are in a continually flicking movement keeping up a stream of fluid (mucus) that carries dust and bacteria away from the lungs.



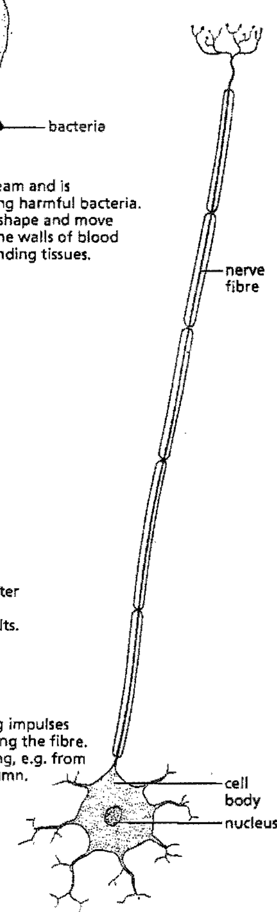
(b) white blood cell
Occurs in the bloodstream and is specialized for engulfing harmful bacteria. It is able to change its shape and move about, even through the walls of blood vessels into the surrounding tissues.



(c) food-conducting cell in a plant (phloem cell)
Long cells, joined end to end, and where they meet, perforations occur in the walls. Through these holes the cytoplasm of one cell communicates with the next. Dissolved food is thought to pass through the holes during its transport through the stem.



(d) root hair cell
These cells, in their thousands, form the outer layer of young roots and present a vast surface for absorbing water and mineral salts. (See Figures 6.14, 7.6 on pp. 57, 63.)



(e) nerve cell
Specialized for conducting impulses of an electrical nature along the fibre. The fibres may be very long, e.g. from the foot to the spinal column.

Figure 1.11 Specialized cells (not to scale)

The specialization of cells to carry out particular functions in an organism is sometimes referred to as **'division of labour'** within the organism. Similarly, the special functions of mitochondria, ribosomes and other cell organelles may be termed 'division of labour' within the cell.

Questions

1 Select from the following events and put them in the correct order for cell division in
   (i) animal cells,
   (ii) plant cells:
   a cytoplasm divides,
   b vacuole forms in one cell,
   c new cell wall separates cells,
   d nucleus divides.

2 Look at Figure 6.2 on p. 51.
   a Whereabouts in a leaf are the food-carrying cells?
   b What other specialized cells are there in the leaf?

Tissues and organs

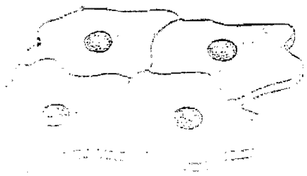
There are some microscopic organisms that consist of one cell only and can carry out all the processes necessary for their survival (see p. 268). The cells of the larger plants and animals cannot survive on their own. A muscle cell could not obtain its own food and oxygen. Other specialized cells have to provide the food and oxygen needed for the muscle cell to live. Unless these cells are grouped together in large numbers and made to work together, they cannot exist for long.

Tissues

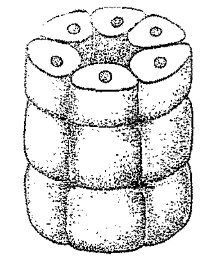
A tissue such as bone, nerve or muscle in animals, and epidermis, phloem or pith (p. 54) in plants, is made up of many hundreds of cells of a few types. The cells of each type have similar structures and functions so that the tissue itself can be said to have a particular function, e.g. nerves conduct impulses, phloem carries food in plants. Figure 1.12 shows how some cells are arranged to form simple tissues.

Organs

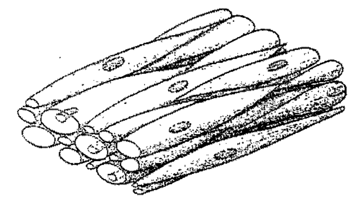
Organs consist of several tissues grouped together to make a structure with a special function. For example, the stomach is an organ which contains tissues made from epithelial cells, gland cells and muscle cells. These cells are supplied with food and oxygen brought by blood vessels. The stomach also has a nerve supply. The heart, lungs, intestines, brain and eyes are further examples of organs in animals. In flowering plants, the root, stem and leaves are the organs. The tissues of the leaf are epidermis, palisade tissue, spongy tissue, xylem and phloem (see pp. 39 and 50–3).



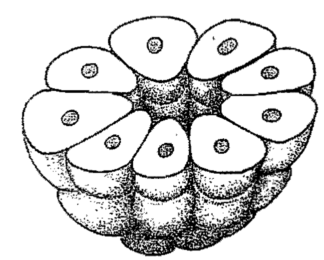
(a) cells forming an epithelium
A thin layer of tissue, e.g. the lining of the mouth cavity. Different types of epithelium form the internal lining of the windpipe, air passages, food canal, etc., and protect these organs from physical or chemical damage.



(b) cells forming a small tube
e.g. a kidney tubule (see p. 132). Tubules such as this carry liquids from one part of an organ to another.



(c) one kind of muscle cell
Forms a sheet of muscle tissue. Blood vessels, nerve fibres and connective tissues will also be present. Contractions of this kind of muscle help to move food along the food canal or to close down small blood vessels.



(d) cells forming part of a gland
The cells make chemicals which are released into the central space and carried away by a tubule such as shown in **(b)**. Hundreds of cell groups like this would form a gland like the salivary gland.

Figure 1.12 How cells form tissues

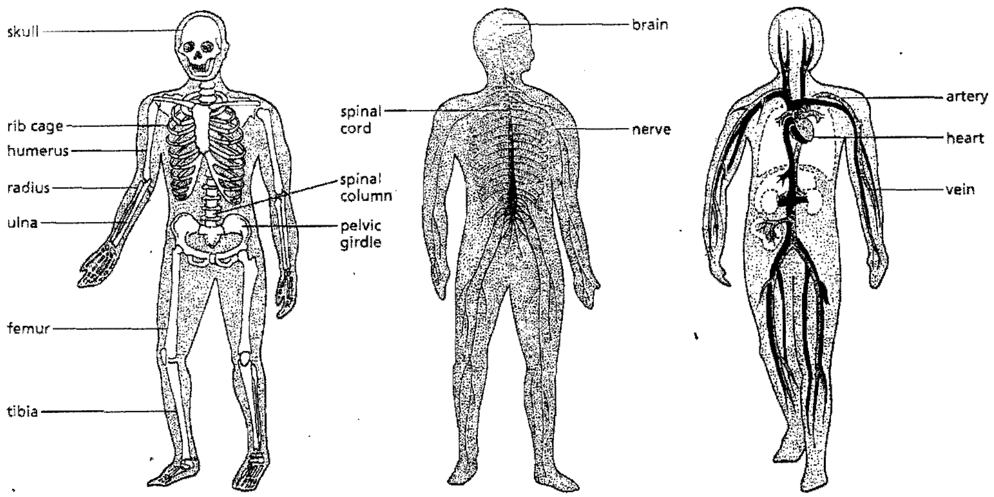
System

A system usually refers to a group of organs whose functions are closely related. For example, the heart and blood vessels make up the **circulatory system**; the brain, spinal cord and nerves make up the **nervous system** (Figure 1.13). In a flowering plant, the stem, leaves and buds make up a system called the shoot (p. 50).

Organism

An organism is formed by the organs and systems working together to produce an independent plant or animal.

An example in the human body of how cells, tissues and organs are related is shown in Figure 1.14.



(a) skeletal system (b) nervous system (c) circulatory system

Figure 1.13 Three examples of systems in the human body

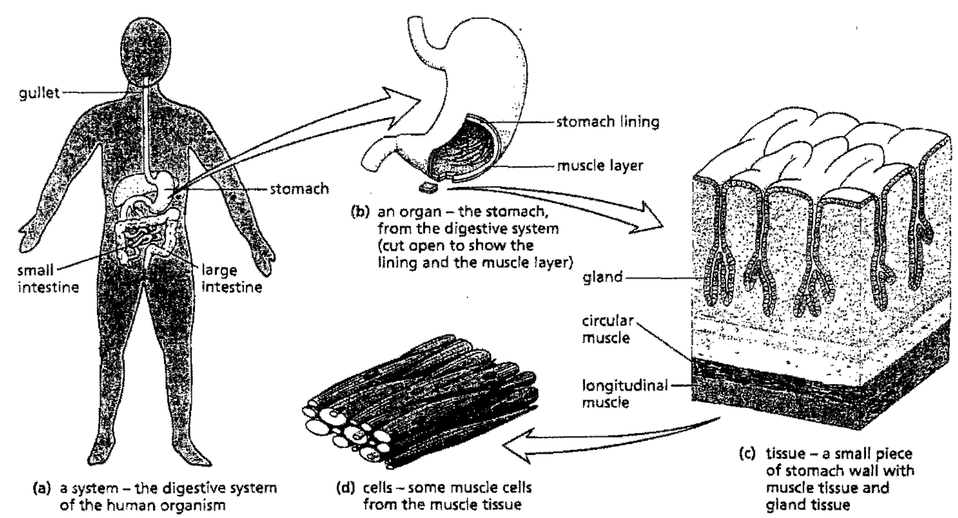


Figure 1.14 An example of how cells, tissues and organs are related

Tissue culture

It is possible to take samples of developing animal tissues, separate the cells by means of enzymes and make the cells grow and divide in shallow dishes containing a nutrient solution. This technique is called **tissue culture**. The cells do not become specialized but may move about, establish contact with each other and eventually cover the floor of the culture dish with a layer, one cell thick. At this point, they stop dividing unless they are separated and transferred to fresh culture vessels. Even so, most mammal cells cease to reproduce after about 20 divisions.

These tissue cultures are used to study cells and cell division, to test out new drugs and vaccines, to culture viruses or to test the effect of possible harmful chemicals. For some tests and experiments, tissue cultures are able to take the place of laboratory animals.

Large-scale tissue cultures are being developed in order to obtain cell chemicals which may be useful in medical treatments.

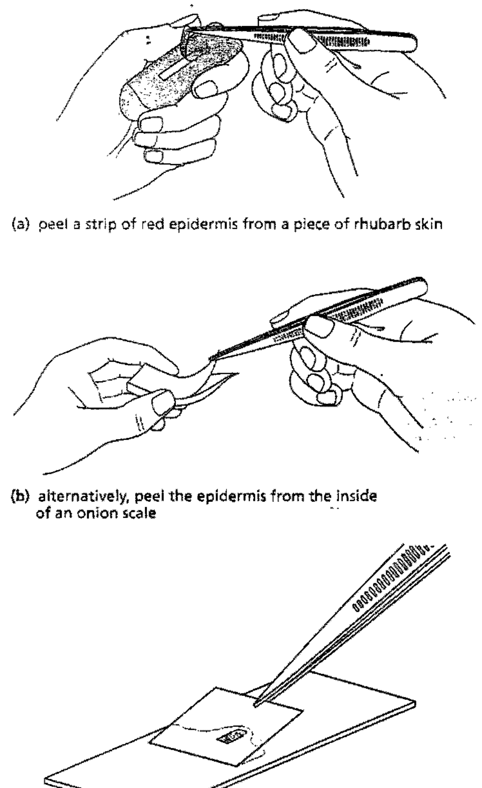
Plant tissue culture is described on p. 81.

Questions

1 Say whether you think the following are cells, tissues, organs or organisms: lungs (p. 123), root hair (p. 56), mesophyll (p. 53), multi-polar neurone (p. 164).

2 What tissues are shown in the following drawings: Figure 36.13 on p. 315; Figure 19.9 on p. 166?

3 Look at Figure 11.5 on p. 99.
  a Which of the structures do you think are organs?
  b What system is represented by the drawing?



(a) peel a strip of red epidermis from a piece of rhubarb skin

(b) alternatively, peel the epidermis from the inside of an onion scale

(c) place the epidermis in a drop of water or weak iodine solution on a slide and carefully lower a cover-slip over it

Figure 1.15 Looking at plant cells

Practical work

1 Plant cells

The outer layer of cells (epidermis) from a stem or an onion scale can be stripped off as shown in Figure 1.15a and b. A piece of onion or a rhubarb stalk is particularly suitable for this. A small piece of this epidermis is placed in a drop of weak iodine solution on a microscope slide and covered with a cover-slip (Figure 1.15c). The tissue is then studied under the microscope. The iodine will stain the cell nuclei pale yellow and the starch grains will stain blue. If red epidermis from rhubarb stalk is used, you will see the red cell sap in the vacuoles.

To see chloroplasts, use fine forceps to pull a leaf from a moss plant, mount it in water on a slide as before and examine it with the high power objective of the microscope (Figure 1.16). At the base of the leaf, the chloroplasts are less densely packed and, therefore, easier to see.

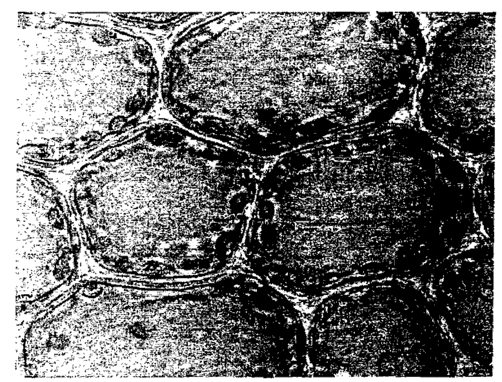


Figure 1.16 Cells in a moss leaf (× 500). The vacuole occupies most of the space in each cell. The chloroplasts are confined to the layer of cytoplasm lining the cell wall

Note The Department of Education and Science recommends that schools no longer use the technique which involves studying the epithelial cells which appear in a smear taken from the inside of the cheek, because of the very small risk of transmitting the AIDS virus. Some Local Education Authorities may therefore forbid the use of this technique in their schools, but the Institute of Biology suggests that if the following procedure is adopted the risk is negligible (*Biologist*, 35 (4) p. 211, September 1988).

Cotton buds from a freshly opened pack are rubbed lightly on the inside of the cheek and gums. The buds are rubbed on to clean slides and then dropped into a container of absolute alcohol. The smear on the slide is covered with a few drops of methylene blue solution before being examined under the microscope (Figure 1.17). The slides are placed in laboratory disinfectant before washing.

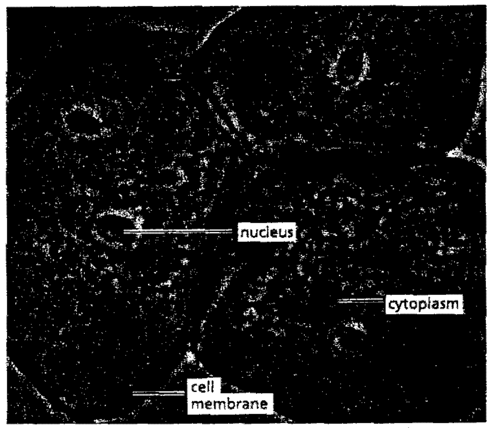


Figure 1.17 Cells from the lining epithelium of the cheek (× 1500)

An alternative method of obtaining cells is to press some 'Sellotape' on to a well-washed wrist. When the tape is removed and studied under the microscope, cells with nuclei can be seen. A few drops of methylene blue solution will stain the cells and make the nuclei more distinct.

Checklist

- Nearly all plants and animals are made up of thousands or millions of microscopic cells.
- All cells contain cytoplasm enclosed in a cell membrane.
- Most cells have a nucleus.
- Cytoplasm contains organelles such as mitochondria, chloroplasts and ribosomes.
- Many chemical reactions take place in the cytoplasm to keep the cell alive.
- The nucleus directs the chemical reactions in the cell and also controls cell division.
- Plant cells have a cellulose cell wall and a large central vacuole.
- Cells are often specialized in their shapes and activities to carry out particular jobs.
- Large numbers of similar cells packed together form a tissue.
- Different tissues arranged together form organs.
- A group of related organs makes up a system.

2 The chemicals of living cells

Cell physiology
Description.

Chemical components of cells
Water, proteins, lipids, carbohydrates, salts, ions, vitamins; their chemical structure and role in the cell. Interconversion of substances in cells.

Enzymes
Definition. Methods of action. Effects of temperature and pH. Enzyme specificity. Intra- and extracellular enzymes.

Practical work
Experiments with enzymes: catalase, starch phosphorylase, pH and temperature.

Cell physiology

The term 'physiology' refers to all the normal functions that take place in a living organism. Digestion of food, circulation of blood and contraction of muscles are some aspects of human physiology. Absorption of water by roots, production of food in the leaves, and growth of shoots towards light are examples of plant physiology. The next three chapters are concerned with physiological events in individual cells.

The physiology of a whole organism is, in some ways, the sum of the physiology of its component cells. If all cells need a supply of oxygen then the whole organism must take in oxygen. Cells need chemical substances to make new cytoplasm and to produce energy. Therefore the organism must take in food to supply the cells with these substances. Of course, it is not quite as simple as this; most cells have specialized functions (p. 6) and so have differing needs. However, all cells need water, oxygen, salts and food substances and all cells consist of water, proteins, lipids, carbohydrates, salts and vitamins or their derivatives.

Chemical components of cells

Water

Most cells contain about 75 per cent of water and will die if their water content falls much below this. Water is a good solvent and many substances move about the cells in a watery solution. Water molecules take part in a great many vital chemical reactions. For example, in green plants, water combines with carbon dioxide to form sugar (see 'Photosynthesis', p. 35). In animals, water helps to break down and dissolve food molecules (see 'Digestion', p. 97).

The physical and chemical properties of water differ from those of most other liquids but make it uniquely effective in supporting living activities. For example, water has a high capacity for heat (high thermal capacity). This means that it can absorb a lot of heat without its temperature rising to levels which damage the proteins in the cytoplasm (see below). However, because water freezes at 0 °C most cells are damaged if their temperature falls below this and ice crystals form in the cytoplasm. (Oddly enough, rapid freezing of cells in liquid nitrogen at below −196 °C does not harm them.)

Proteins

Some proteins contribute to the structures of the cell, e.g. to the cell membranes, the mitochondria, ribosomes and chromosomes. These proteins are called **structural proteins.**

There is another group of proteins called **enzymes.** Enzymes are present in the membrane systems, in the mitochondria, in special vacuoles and in the fluid part of the cytoplasm. Enzymes control the chemical reactions which keep the cell alive (see p. 14).

Although there are many different types of protein, all contain carbon, hydrogen, oxygen and nitrogen, and many contain sulphur. Their molecules are made up of long chains of simpler chemicals called **amino acids.** There are about 20 different amino acids in animal proteins, including alanine, leucine, valine, glutamine, cysteine, glycine and lysine. A small protein molecule might be made up from a chain consisting of a hundred or so amino acids, e.g. glycine–valine–valine–cysteine–leucine–glutamine–, etc. Each type of protein has its amino acids arranged in a particular order.

The chain of amino acids in a protein takes up a particular shape as a result of cross-linkages. Cross-linkages form between amino acids which are not neighbours, as shown in Figure 2.1. The shape of a protein molecule has a very important effect on its reactions with substances, as explained in 'Enzymes' on p. 14.

When a protein is heated to temperatures over 50 °C, the cross-linkages in its molecules break down; the protein molecules lose their shape and will not usually regain it even when cooled. The protein is said to have been **denatured.** Because the shape of the molecules has been altered, the protein will have lost its original properties.