20 Biotechnology and genetic engineering

Biotechnology and genetic engineering
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Reasons why bacteria are useful in biotechnology and genetic engineering

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Biotechnology and genetic engineering

Biotechnology is the application of biological organisms, systems or processes to manufacturing and service industries. **Genetic engineering** involves the transfer of genes from one organism to (usually) an unrelated species.

Both processes often make use of bacteria because of their ability to make complex molecules (proteins for example) and their rapid reproduction rate.

Use of bacteria in biotechnology and genetic engineering

Bacteria are useful in biotechnology and genetic engineering because they can be grown and manipulated without raising ethical concerns. They have a genetic code that is the same as all other organisms, so genes from other animals or plants can be successfully transferred into bacterial DNA.

Bacterial DNA is in the form of a circular strand and also small circular pieces called **plasmids**. Scientists have developed techniques to cut open these plasmids and insert sections of DNA from other organisms into them. When the bacterium divides, the DNA in the modified plasmid is copied, including the 'foreign' DNA. This may contain a gene to make a particular protein such as insulin, which can be extracted and used as a medicine to treat diabetes.

Biotechnology

Although biotechnology is 'hot news', we have been making use of it for hundreds of years. Wine-making, the brewing of beer, the baking of bread and the production of cheese all depend on fermentation processes brought about by yeasts, other fungi and bacteria, or enzymes from these organisms.

Antibiotics, such as penicillin, are produced by mould fungi or bacteria. The production of industrial chemicals such as citric acid or lactic acid needs bacteria or fungi to bring about essential chemical changes.

Sewage disposal (Chapter 21) depends on bacteria in the filter beds to form the basis of the food chain that purifies the effluent.

Biotechnology is not concerned solely with the use of micro-organisms. Cell cultures and enzymes also feature in modern developments. In this chapter, however, there is space to consider only a representative sample of biotechnological processes that use micro-organisms.

Biofuels

The term 'fermentation' does not apply only to alcoholic fermentation but to a wide range of reactions, brought about by enzymes or micro-organisms. In Chapter 12, the anaerobic respiration of glucose to alcohol or lactic acid was described as a form of fermentation.

Micro-organisms that bring about fermentation are using the chemical reaction to produce energy, which they need for their living processes. The reactions that are useful in fermentation biotechnology are mostly those that produce incompletely oxidised compounds. A reaction that goes all the way to carbon dioxide and water is not much use in this context.

The micro-organisms are encouraged to grow and multiply by providing nutrients such as glucose, with added salts and, possibly, vitamins. Oxygen or air is bubbled through the culture if the reaction is aerobic, or excluded if the process is anaerobic. An optimum pH and temperature are maintained for the species of microbe being cultured.

In 'Conservation' in Chapter 21, it is pointed out that ethanol (alcohol), produced from fermented sugar or surplus grain, could replace, or at least supplement, petrol.

Brazil, Zimbabwe and the USA produce ethanol as a renewable source of energy for the motor car. Since 1990, 30% of new cars in Brazil can use ethanol and many more use a mixture of petrol and ethanol. As well as being a renewable resource, ethanol produces less pollution than petrol.

However, biofuels are not yet economical to produce. For example, the energy used to grow, fertilise and harvest sugar-cane, plus the cost of extracting the sugar and converting it to ethanol, uses more energy than the ethanol releases when burned.

In addition, there are also environmental costs, some of which will be outlined in Chapter 21. Forests are being destroyed to plant soy beans or oil palms, removing the habitats of thousands of organisms, some of which, such as the orang-utan, are on the verge of extinction.

Another biofuel, oil from rapeseed or sunflower seed, can with suitable treatment replace diesel fuel. It is less polluting than diesel but more expensive to produce.

Bread

Yeast is the micro-organism used in bread-making but the only fermentation product needed is carbon dioxide. The carbon dioxide makes bubbles in the bread dough. These bubbles make the bread 'light' in texture.

Flour, water, salt, oil and yeast are mixed to make a dough. Yeast has no enzymes for digesting the starch in flour but the addition of water activates the amylases already present in flour and these digest some of the starch to sugar. With highly refined white flour, it may be necessary to add sugar to the dough. The yeast then ferments the sugar to alcohol and carbon dioxide.

A protein called **gluten** gives the dough a sticky, plastic texture, which holds the bubbles of gas. The dough is repeatedly folded and stretched ('kneaded') either by hand, in the home, or mechanically in the bakery. The dough is then left for an hour or two at a temperature of about 27 °C while the yeast does its work. The accumulating carbon dioxide bubbles make the dough rise to about double its volume (Figure 20.1). The dough may then be kneaded again or put straight into baking tins and into an oven at about 200 °C. This temperature makes the bubbles expand more, kills the yeast and evaporates the small quantities of alcohol before the dough turns into bread.

Figure 20.1 Carbon dioxide produced by the yeast has caused the dough to rise.

Enzymes

Enzymes can be produced by commercial fermentation using readily available feedstocks such as corn-steep liquor or molasses. Fungi (e.g. *Aspergillus*) or bacteria (e.g. *Bacillus*) are two of the commonest organisms used to produce the enzymes.

These organisms are selected because they are non-pathogenic and do not produce antibiotics. The fermentation process is similar to that described for penicillin. If the enzymes are extracellular (Chapter 5) then the liquid feedstock is filtered from the organism and the enzyme is extracted (Figure 20.2). If the enzymes are intracellular, the micro-organisms have to be filtered from the feedstock. They are then crushed and the enzymes extracted with water or other solvents.

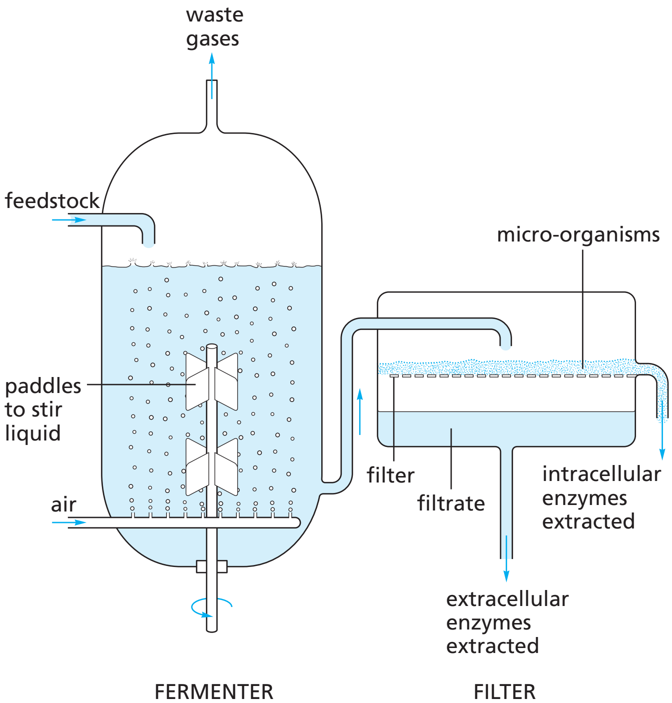

Figure 20.2 Principles of enzyme production from micro-organisms

Using the techniques of genetic engineering, new genes can be introduced into the microbes to 'improve' the action of the enzymes coded for by the genes (e.g. making the enzymes more heat stable).

One effective way of using enzymes is by 'immobilising' them. The enzymes or the micro-organisms that produce them are held in or on beads or membranes of an insoluble and inert substance, e.g. plastic. The beads or membranes are packed into columns and the substrate is poured over them at the optimum rate. This method has the advantage that the enzyme is not lost every time the product is extracted. Immobilised enzymes also allow the process to take place in a continuous way rather than a batch at a time.

Some commercial uses of enzymes are listed below.

- **Proteases**: In washing powders for dissolving stains from, e.g. egg, milk and blood; removing hair from animal hides; cheese manufacture; tenderising meat.
- **Lipases**: Flavour enhancer in cheese; in washing powders for removal of fatty stains.
- **Pectinases**: Clarification of fruit juices; maximising juice extraction.
- **Amylases**: Production of glucose from starch.

Pectinases are used to separate the juices from fruit such as apples. The enzymes can be extracted from fungi such as *Aspergillus niger*. They work by breaking down pectin, the jelly-like substance that sticks plant cell walls to each other. The enzymes can also be used to clarify fruit juice and wine (make it more transparent). During the breakdown process, a number of different polysaccharides are released, which make the juice cloudy, but pectinases break these down to make the juice clearer. The sugars produced also make the juice sweeter.

Biological washing powders

The majority of commercial enzyme production involves protein-digesting enzymes (proteases) and fat-digesting enzymes (lipases) for use in the food and textile industries. When combined in washing powders they are effective in removing stains in clothes caused by proteins, e.g. blood, egg and gravy, and fats, e.g. grease. Protein and fat molecules tend to be large and insoluble. When they have been digested the products are small, soluble molecules, which can pass out of the cloth.

Biological washing powders save energy because they can be used to wash clothes at lower temperatures, so there is no need to boil water. However, if they are put in water at higher temperatures the enzymes become denatured (see Chapter 5) and they lose their effectiveness.

Practical work

Investigating the use of pectinase in fruit juice production

- Make 100 cm^3 of apple purée using a liquidiser, or use a tin of apple purée.
- Transfer the purée to a 250 cm^3 beaker.
- Add one level teaspoon of powdered pectinase enzyme (care needed – see safety note), stir the mixture and leave it for about 5 minutes.
- Place a funnel in the top of a 100 cm^3 measuring cylinder and line the funnel with a folded filter paper.
- Transfer the purée into the filter funnel and leave it in a warm place for up to 24 hours.
- Other measuring cylinders could be set up in the same way, with purée left to stand at different temperatures to compare the success of juice extraction.

Safety note: Take care to avoid skin or eye contact with the enzyme powder. Enzyme powder can cause allergies. Wipe up any spillages immediately and rinse the cloth thoroughly with water. Do not allow spillages to dry up.

Result
Juice is extracted from the purée. It collects in the measuring cylinder and is transparent (it has been clarified).

Interpretation
Pectinase breaks down the apple tissue, releasing sugars in solution. More juice collects in the measuring cylinder when the purée has been kept in warm conditions; colder temperatures slow down the process.

Further investigation
If other enzymes are available, try comparing cellulase and amylase with pectinase. Combinations of these could be used to find out which is the most effective in extracting the juice. Remember to control variables to make a fair comparison.

Investigating the use of biological washing powder

- Break an egg into a plastic beaker and whisk it with a fork, spatula or stirring rod until thoroughly mixed.
- Cut up four pieces of white cloth to make squares 10 cm × 10 cm, smear egg evenly onto each of them and leave to dry.
- Set up four 250 cm^3 beakers as follows:
  A 100 cm^3 warm water, with no washing powder.
  B 5 cm^3 (1 level teaspoon) of non-biological washing powder dissolved in 100 cm^3 warm water.
  C 5 cm^3 (1 level teaspoon) of biological washing powder dissolved in 100 cm^3 warm water.
  D 5 cm^3 (1 level teaspoon) of biological washing powder dissolved in 100 cm^3 water and boiled for 5 minutes, then left to cool until warm.
- Place a piece of egg-stained cloth in each beaker and leave for 30 minutes.
- Remove the pieces of cloth and compare the effectiveness of each washing process.

Results
The piece of cloth in beaker **C** is most effectively cleaned, followed by **B** and then **D**. The cloth in **A** is largely unchanged.

Interpretation
The enzymes in the biological washing powder break down the proteins and fats in the egg stain to amino acids and fatty acids and glycerol. These are smaller, soluble molecules, which can escape from the cloth and dissolve in the water. Non-biological washing powder is less effective because it does not contain enzymes. Boiled biological washing powder is not very effective because the enzymes in it have been denatured. Beaker **A** was a control, with no active detergent or enzymes. Soaking the cloth in warm water alone does not remove the stain.

Lactose-free milk

Lactose is a type of disaccharide sugar found in milk and dairy products. Some people suffer from **lactose intolerance**, a digestive problem where the body does not produce enough of the enzyme lactase. As a result, the lactose remains in the gut, where it is fermented by bacteria, causing symptoms such as flatulence (wind), diarrhoea and stomach pains. Many foods contain dairy products, so people with lactose intolerance cannot eat them, or suffer the symptoms described above. However, lactose-free milk is now produced using the enzyme lactase.

The lactase can be produced on a large scale by fermenting yeasts such as *Kluyveromyces fragilis* or fungi such as *Aspergillus niger*. The fermentation process is shown in Figure 20.2.

A simple way to make lactose-free milk is to add lactase to milk. The enzyme breaks down lactose sugar into two monosaccharide sugars: glucose and galactose. Both can be absorbed by the intestine.

An alternative, large-scale method is to immobilise lactase on the surface of beads. The milk is then passed over the beads and the lactose sugar is effectively removed. This method avoids having the enzyme molecules in the milk because they remain on the beads.

The food industry uses lactase in the production of milk products such as yoghurt: it speeds up the process and makes the yoghurt taste sweeter.

Practical work

Action of lactase

This investigation uses glucose test strips (diastix). They are used by people with diabetes to test for glucose in their urine (see 'Homeostasis' in Chapter 14 for details of diabetes). The strips do not react to the presence of other sugars (lactose, sucrose, etc.)

- Pour 25 cm^3 warm, fresh milk into a 100 cm^3 beaker.
- Test the milk for glucose with a glucose test strip.
- Measure out 2 cm^3 of 2% lactase using a syringe or pipette and add this to the milk.

- Stir the mixture and leave for a few minutes.
- Test the milk again with a new glucose test strip.

Result
Milk gives a negative result for glucose, but milk exposed to lactase gives a positive result.

Interpretation
Lactase breaks down the lactose in milk, as shown in the equation below.

$$\text{lactose} \xrightarrow{\text{lactase}} \text{glucose} + \text{galactose}$$

Note: milk sometimes contains traces of glucose. If the milk gives a positive result with the glucose test strip, an alternative method would be to use a solution of lactose instead of milk. However, the amount of glucose in the milk, as indicated by the colour change on the test strip, should increase after treatment with lactase.

Antibiotics

When micro-organisms are used for the production of antibiotics, it is not their fermentation products that are wanted, but complex organic compounds, called **antibiotics**, that they synthesise.

Most of the antibiotics we use come from bacteria or fungi that live in the soil. The function of the antibiotics in this situation is not clear. One theory suggests that the chemicals help to suppress competition for limited food resources, but the evidence does not support this theory.

One of the most prolific sources of antibiotics is *Actinomycetes*. These are filamentous bacteria that resemble microscopic mould fungi. The actinomycete *Streptomyces* produces the antibiotic **streptomycin**.

Perhaps the best known antibiotic is **penicillin**, which is produced by the mould fungus *Penicillium* and was discovered by Sir Alexander Fleming in 1928. Penicillin is still an important antibiotic but it is produced by mutant forms of a different species of *Penicillium* from that studied by Fleming (Figure 20.3). The different mutant forms of the fungus produce different types of penicillin.

The penicillin types are chemically altered in the laboratory to make them more effective and to 'tailor' them for use with different diseases. 'Ampicillin', 'methicillin' and 'oxacillin' are examples.

Antibiotics attack bacteria in a variety of ways. Some of them disrupt the production of the cell wall and so prevent the bacteria from reproducing, or even cause them to burst open; some interfere with protein synthesis and thus arrest bacterial growth. Those that stop bacteria from reproducing are said to be **bacteriostatic**; those that kill the bacteria are **bacteriocidal**.

Figure 20.3 A laboratory fermenter for antibiotic production, which will eventually be scaled up to 10 000-litre fermentation vessels.

Animal cells do not have cell walls, and the cell structures involved in protein production are different. Consequently, antibiotics do not damage human cells although they may produce some side-effects such as allergic reactions.

Commercial production of penicillin

Antibiotics are produced in giant fermenting tanks, up to 100 000 litres in capacity. The tanks are filled with a nutrient solution. For penicillin production, the carbohydrate source is sugar, mainly lactose or 'corn-steep liquor' – a by-product of the manufacture of cornflour and maize starch; it contains amino acids as well as sugars. Mineral salts are added, the pH is adjusted to between 5 and 6, the temperature is maintained at about 26 °C, air is blown through the liquid and it is stirred. The principles of industrial fermentation are shown in Figure 20.2. The nutrient liquid is seeded with a culture of the appropriate micro-organism, which is allowed to grow for a day or two. Sterile conditions are essential. If 'foreign' bacteria or fungi get into the system they can completely disrupt the process. As the nutrient supply diminishes, the micro-organisms begin to secrete their antibiotics into the medium.

The nutrient fluid containing the antibiotic is filtered off and the antibiotic extracted by crystallisation or other methods.

Genetic engineering

Key definition
Genetic engineering is changing the genetic material of an organism by removing, changing or inserting individual genes.

Applications of genetic engineering

The following section gives only a few examples of genetic engineering, a rapidly advancing process. Some products, such as insulin, are in full-scale production. A few **genetically modified** (**GM**) crops, e.g. maize and soya bean, are being grown on a large scale in the USA. Many other projects are still at the experimental stage, undergoing trials, awaiting approval by regulatory bodies or simply on a 'wish list'.

Production of human insulin

This hormone can be produced by genetically modified bacteria and has been in use since 1982. The human insulin gene is inserted into bacteria, which then secrete human insulin. The human insulin produced in this way (Figure 20.4) is purer than insulin prepared from pigs or cattle, which sometimes provokes allergic reactions owing to traces of 'foreign' protein. The GM insulin is acceptable to people with a range of religious beliefs who may not be allowed to use insulin from cows or pigs.

GM crops

Genetic engineering has huge potential benefits in agriculture but, apart from a relatively small range of crop plants, most developments are in the experimental or trial stages. In the USA, 50% of the soya bean crop and 30% of the maize harvest consist of genetically modified plants, which are resistant to herbicides and insect pests.

In the UK at the moment, GM crops are grown only on a trial basis and there is resistance to their growth and the presence of GM products in food.

Figure 20.4 Human insulin prepared from genetically engineered bacteria. Though free from foreign proteins, it does not suit all patients.

Pest resistance

The bacterium, *Bacillus thuringiensis*, produces a toxin that kills caterpillars and other insect larvae. The toxin has been in use for some years as an insecticide. The gene for the toxin has been successfully introduced into some plant species using a bacterial vector. The plants produce the toxin and show increased resistance to attack by insect larvae. The gene is also passed on to the plant's offspring. Unfortunately there are signs that insects are developing immunity to the toxin.

Most American GM maize, apart from its herbicide-resistant gene, also carries a pesticide gene, which reduces the damage caused by a stem-boring larva of a moth (Figure 20.5).

Figure 20.5 The maize stem borer can cause considerable losses by killing young plants.

Figure 20.6 Genetically engineered tomatoes. In the three engineered tomatoes on the right, biologists have deleted the gene that produces the enzyme which makes fruit go soft.

Herbicide resistance

Some of the safest and most effective herbicides are those, such as glyphosate, which kill any green plant but become harmless as soon as they reach the soil. These herbicides cannot be used on crops because they kill the crop plants as well as the weeds. A gene for an enzyme that breaks down glyphosate can be introduced into a plant cell culture (Chapter 16). This should lead to a reduced use of herbicides.

Modifying plant products

A gene introduced to oilseed rape and other oil-producing plants can change the nature of the oils they produce to make them more suitable for commercial processes, e.g. detergent production. This might be very important when stocks of petroleum run out. It could be a renewable source of oil, which would not contribute to global warming (see 'Pollution' in Chapter 21).

The tomatoes in Figure 20.6 have been modified to improve their keeping qualities.

Extension work

Other applications of genetic engineering

One of the objections to GM crops is that, although they show increased yields, this has benefited only the farmers and the chemical companies in the developed world. So far, genetic engineering has done little to improve yields or quality of crops in the developing world, except perhaps in China. In fact, there are a great many trials in progress, which hold out hopes of doing just that. Here are just a few.

Inadequate intake of iron is one of the major dietary deficiencies (Chapter 7) worldwide. An enzyme in some plant roots enables them to extract more iron from the soil. The gene for this enzyme can be transferred to plants, such as rice, enabling them to extract iron from iron-deficient soils.

Over 100 million children in the world are deficient in vitamin A. This deficiency often leads to blindness. A gene for beta-carotene, a precursor of vitamin A, can be inserted into plants to alleviate this widespread deficiency. This is not, of course, the only way to increase vitamin A availability but it could make a significant contribution.

Some acid soils contain levels of aluminium that reduce yields of maize by up to 8%. About 40% of soils in tropical and subtropical regions have this problem. A gene introduced into maize produces citrate, which binds the aluminium in the soil and releases phosphate ions. After 15 years of trials, the GM maize was made available to farmers, but pressure from environmental groups has blocked its adoption.

As a result of irrigation, much agricultural land has become salty and unproductive. Transferring a gene for salt tolerance from, say, mangrove plants to crop plants could bring these regions back into production.

If the gene, or genes, for nitrogen fixation (Chapter 19) from bacteria or leguminous plants could be introduced to cereal crops, yields could be increased without the need to add fertilisers.

Similarly, genes for drought resistance would make arid areas available for growing crops.

Genes coding for human vaccines have been introduced into plants.

Hepatitis B vaccine

The gene for the protein coat of the hepatitis virus is inserted into yeast cells. When these are cultured, they produce a protein that acts as an antigen (a vaccine, Chapter 10) and promotes the production of antibodies to the disease.

Transgenic plants have been engineered to produce vaccines that can be taken effectively by mouth. These include vaccines against rabies and cholera. Several species of plant have been used, including the banana, which is cheap and widespread in the tropics, can be eaten without cooking and does not produce seeds (Figure 20.7).

Figure 20.7 It is important to ensure that plants engineered to produce drugs and vaccines cannot find their way, by chance, into the human food chain. Strict control measures have to be applied.

Possible hazards of GM crops

One of the possible harmful effects of planting GM crops is that their modified genes might get into wild plants. If a gene for herbicide resistance found its way, via pollination, into a 'weed' plant, this plant might become resistant to herbicides and so become a 'super weed'. The purpose of field trials is to assess the likelihood of this happening. Until it is established that this is a negligible risk, licences to grow GM crops will not be issued.

To prevent the transfer of pollen from GM plants, other genes can be introduced, which stop the plant from producing pollen and induce the seeds and fruits to develop without fertilisation. This is a process that occurs naturally in many cultivated and wild plants.

Apart from specific hazards, there is also a sense of unease about introducing genes from one species into a totally different species. This is something that does not happen 'in nature' and therefore long-term effects are not known. In conventional cross-breeding, the genes transferred come from the same, or a closely related, species. However, in cross-breeding the whole raft of genes is transferred and this has sometimes had bad results when genes other than the target genes have combined to produce harmful products. Genetic engineering offers the advantage of transferring only those genes that are required.

The differences between the genetic make-up of different organisms is not as great as we tend to think. Plants and animals share 60% of their genes and humans have 50% of their genes in common with fruit flies. Not all genetic engineering involves transfer of 'alien' genes. In some cases it is the plant's own genes that are modified to improve its success in the field.

At least some of the protests against GM crops may be ill-judged (Figure 20.8).

Figure 20.8 Ill-judged protest. These vandalised poplars carried a gene that softened the cell walls, reducing the need for environmentally damaging chemicals used in paper making. They were also all female plants so no pollen could have been produced.

Use of bacteria and restriction enzymes in genetic engineering

To understand the principles of genetic engineering you need to know something about bacteria (Figure 1.29) and **restriction enzymes**.

Bacteria are microscopic single-celled organisms with cytoplasm, cell membranes and cell walls, but without a proper nucleus. Genetic control in a bacterium is exercised by a double strand of deoxyribonucleic acid (DNA) in the form of a circle, but not enclosed in a nuclear membrane. This circular DNA strand carries the genes that control bacterial metabolism.

In addition, there are present in the cytoplasm a number of small, circular pieces of DNA called **plasmids**. The plasmids often carry genes that give the bacterium resistance to particular antibiotics such as tetracycline and ampicillin.

Restriction enzymes are produced by bacteria. They 'cut' DNA molecules at specific sites, e.g. between the A and the T in the sequence GAA–TTC. Restriction enzymes can be extracted from bacteria and purified. By using a selected restriction enzyme, DNA molecules extracted from different organisms can be cut at predictable sites and made to produce lengths of DNA that contain specific genes.

DNA from human cells can be extracted and restriction enzymes used to 'cut' out a sequence of DNA that includes a gene, e.g. the gene for production of insulin (Figure 20.9). These lengths have sticky ends. Plasmids are extracted from bacteria and 'cut open' with the same restriction enzyme. If the human DNA is then added to a suspension of the plasmids, some of the human DNA will attach to some of the plasmids by their sticky ends, and the plasmids will then close up again, given suitable enzymes such as **ligase**. The DNA in these plasmids is called **recombinant DNA**.

The bacteria can be induced to take up the plasmids and, by ingenious culture methods using antibiotics, it is possible to select the bacteria that contain the recombinant DNA. The human DNA in the plasmids continues to produce the same protein as it did in the human cells. In the example mentioned, this would be the protein, insulin (Chapter 14). The plasmids are said to be the **vectors** that carry the human DNA into the bacteria and the technique is sometimes called **gene-splicing**.

Given suitable nutrient solutions, bacteria multiply rapidly and produce vast numbers of offspring. The bacteria reproduce by mitosis (Chapter 17) and so each daughter bacterium will contain the same DNA and the same plasmids as the parent. The offspring form a clone and the insulin gene is said to be cloned by this method.

The bacteria are cultured in special vessels called **fermenters** (Figure 20.2) and the insulin that they produce can be extracted from the culture medium and purified for use in treating diabetes (Chapter 14).

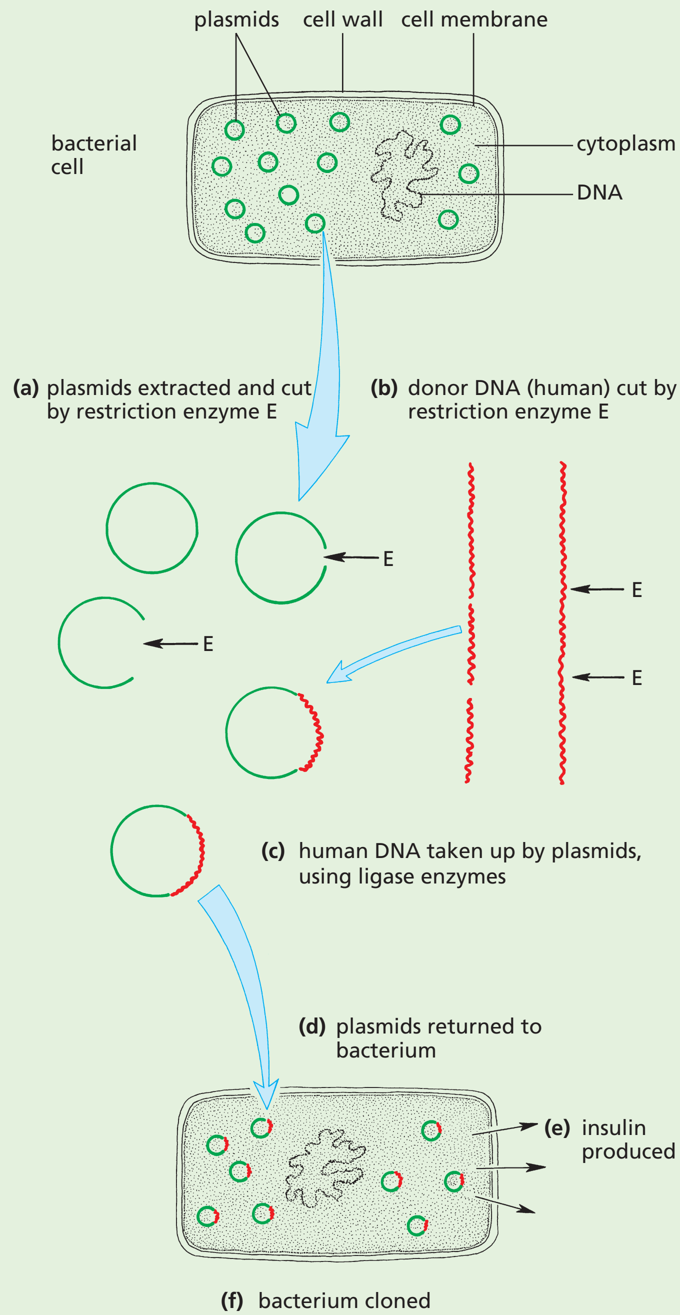

Figure 20.9 The principles of genetic engineering

This is only one type of genetic engineering. The vector may be a virus rather than a plasmid; the DNA may be inserted directly, without a vector; the donor DNA may be synthesised from nucleotides rather than extracted from cells; yeast may be used instead of bacteria. The outcome, however, is the same. DNA from one species is inserted into a different species and made to produce its normal proteins (Figure 20.9).

In the example shown in Figure 20.9, the gene product, insulin, is harvested and used to treat diabetes. In other cases, genes are inserted into organisms to promote changes that may be beneficial. Bacteria or viruses are used as vectors to deliver the genes. For example, a bacterium is used to deliver a gene for herbicide resistance in crop plants.

GM food

This is food prepared from GM crops. Most genetic modifications are aimed at increasing yields rather than changing the quality of food. However, it is possible to improve the protein, mineral or vitamin content of food and the keeping qualities of some products (Figure 20.6).

Possible hazards of GM food

One of the worries is that the vectors for delivering recombinant DNA contain genes for antibiotic resistance. The antibiotic-resistant properties are used to select only those vectors that have taken up the new DNA. If, in the intestine, the DNA managed to get into potentially harmful bacteria, it might make them resistant to antibiotic drugs.

Although there is no evidence to suggest this happens in experimental animals, the main biotech companies are trying to find methods of selecting vectors without using antibiotics.

Another concern is that GM food could contain pesticide residues or substances that cause allergies (allergens). However, it has to be said that all GM products are rigorously tested for toxins and allergens over many years, far more so than any products from conventional cross-breeding. The GM products have to be passed by a series of regulatory and advisory bodies before they are released on to the market. In fact only a handful of GM foods are available. One of these is soya, which is included, in one form or another, in 60% of processed foods.

Golden rice was a variety of rice developed through genetic engineering to carry a gene that is responsible for making beta-carotene, a precursor of vitamin A. In countries where rice is a staple food, the use of golden rice could reduce the incidence of a condition called night blindness – a serious problem which is estimated to kill 670 000 children under the age of 5 each year.

However, some argue that there is a danger of the precursor changing into other, toxic chemicals once eaten. There were also concerns about a reduction in biodiversity as a result of the introduction of GM species. Subsistence farmers could also be tied to large agricultural suppliers who may then manipulate seed prices.

Questions

Core

1 Outline the biology involved in making bread.

2 How is DNA in a bacterium different from DNA in an animal cell?

3 Outline three commercial uses of enzymes.

Extension

4 Give two reasons why bacteria are more suitable for use in genetic engineering than, for example, mammals.

5 a With reference to their sources, explain why ethanol is described as a renewable energy source while petrol is described as a non-renewable source.

b Use of a renewable source of energy such as ethanol for fuel in motor cars seems like a good solution to fuel shortages. What are the disadvantages of using ethanol?

6 Some people are lactose-intolerant. Explain how biotechnology can be used to allow people with this condition to eat milk products.

7 Make a table to outline the advantages and disadvantages of GM crops.

8 How can genetic engineering be used to solve major worldwide dietary deficiencies such as vitamin and mineral deficiencies?

Checklist

After studying Chapter 20 you should know and understand the following:

Biotechnology and genetic engineering

- Bacteria are useful in biotechnology and genetic engineering because of their ability to make complex molecules and their rapid reproduction.

- Bacteria are useful in biotechnology and genetic engineering because of lack of ethical concerns over their manipulation and growth.
- The genetic code in bacteria is shared with all other organisms.
- Bacteria contain DNA in the form of plasmids, which can be cut open to insert genes.

Biotechnology

- Biotechnology is the application of living organisms, systems or processes in industry.
- Many biotechnological processes use micro-organisms (fungi and bacteria) to bring about the reactions.
- Most biotechnological processes are classed as 'fermentations'.
- Fermentation may be aerobic or anaerobic.
- The required product of biotechnology may be the organism itself (e.g. mycoprotein) or one of its products (e.g. alcohol).
- Yeasts produce ethanol by anaerobic respiration. The ethanol can be produced commercially for biofuel.
- Anaerobic respiration by yeast is also involved in bread-making.
- Pectinase can be used to extract fruit juices.
- Lipase and protease enzymes are used in biological washing powders to remove fat and protein stains.

- Lactase is used to produce lactose-free milk.
- Antibiotics are produced from bacteria and fungi.
- The fungus *Penicillium* is used in the production of the antibiotic penicillin.
- Fermenters are used in the production of penicillin.
- Enzymes from micro-organisms can be produced on an industrial scale and used in other biotechnology processes.
- Sterile conditions are essential in biotechnology to avoid contamination by unwanted microbes.

Genetic engineering

- Genetic engineering is changing the genetic material of an organism by removing, changing or inserting individual genes.
- Examples of genetic engineering include:
  - the insertion of humans genes into bacteria to produce human insulin
  - the insertion of genes into crop plants to confer resistance to herbicides or insect pests
  - the insertion of genes into crop plants to provide additional vitamins.
- Plasmids and viruses are vectors used to deliver the genes.
- Genetic engineering is used in the production of enzymes, hormones and drugs.
- Crop plants can be genetically modified to resist insect pests and herbicides.
- There is concern that the genes introduced into crop plants might spread to wild plants.

- Genetic engineering can use bacteria to produce human protein, such as insulin.
- Human gene DNA is isolated using restriction enzymes, forming sticky ends.
- Bacterial plasmid DNA is cut with same restriction enzymes, forming matching sticky ends.
- Human gene DNA is inserted into the bacterial plasmid DNA using DNA ligase to form a recombinant plasmid.
- The plasmid is inserted into bacteria.
- The bacteria containing the recombinant plasmid are replicated.
- They make a human protein as they express the gene.
- There are advantages and disadvantages of genetically modifying crops, such as soya, maize and rice.

21 Human influences on ecosystems

Food supply
Use of modern technology in increased food production
Negative impacts of monocultures and intensive livestock production to an ecosystem

Social, environmental and economic implications of providing sufficient food for an increasing human global population

Habitat destruction
Reasons for habitat destruction
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Effects of deforestation on habitats

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Food supply

A few thousand years ago, most of the humans on the Earth obtained their food by gathering leaves, fruits or roots and by hunting animals. The population was probably limited by the amount of food that could be collected in this way.

Human faeces, urine and dead bodies were left on or in the soil and so played a part in the nitrogen cycle (Chapter 19). Life may have been short, and many babies may have died from starvation or illness, but humans fitted into the food web and nitrogen cycle like any other animal.

Once agriculture had been developed, it was possible to support much larger populations and the balance between humans and their environment was upset.

Intensification of agriculture

Forests and woodland are cut down in order to grow more food. This destroys important wildlife habitats and may affect the climate. Tropical rainforest is being cut down at the rate of 111 400 square kilometres per year. Since 1950, between 30 and 50% of British deciduous woodlands have been felled to make way for farmland or conifer plantations.

Modern **agricultural machinery** is used to clear the land, prepare the soil and plant, maintain and harvest crops to improve efficiency. To make the process even more efficient, fields are made larger by taking out hedges (Figure 21.1).

Figure 21.1 Destruction of a hedgerow. Permission now has to be sought from the local authority before this can happen. Grants are available in some countries to replant hedges.

Larger vehicles such as tractors (see Figure 21.6) and combine harvesters (see Figure 21.5) can then be used in the fields to speed up the farming processes. However, studies have shown that repeated ploughing of a pasture reduces the number of species in the soil.

The use of chemical fertilisers to improve yield

In a natural community of plants and animals, the processes that remove and replace mineral elements in the soil are in balance. In agriculture, most of the crop is usually removed so that there is little or no organic matter for nitrifying bacteria to act on. In a farm with animals, the animal manure, mixed with straw, is ploughed back into the soil or spread on the pasture. The manure thus replaces the nitrates and other minerals removed by the crop. It also gives the soil a good structure and improves its water-holding properties.

When animal manure is not available in large enough quantities, **chemical fertilisers** are used. These are mineral salts made on an industrial scale. Examples are ammonium sulfate (for nitrogen and sulfur), ammonium nitrate (for nitrogen) and compound NPK fertiliser for nitrogen, phosphorus and potassium. These are spread on the soil in carefully calculated amounts to provide the minerals, particularly nitrogen, phosphorus and potassium, which the plants need. These artificial fertilisers increase the yield of crops from agricultural land, but they do little to maintain a good soil structure because they contain no organic matter (Figures 21.2 and 21.3). In some cases, their use results in the pollution of rivers and streams (see 'Pollution' later in this chapter).

Monoculture

The whole point of crop farming is to remove a mixed population of trees, shrubs, wild flowers and grasses (Figure 21.4) and replace it with a dense population of only one species such as wheat or beans (Figure 21.5). When a crop of a single species is grown on the same land, year after year, it is called a **monoculture**.

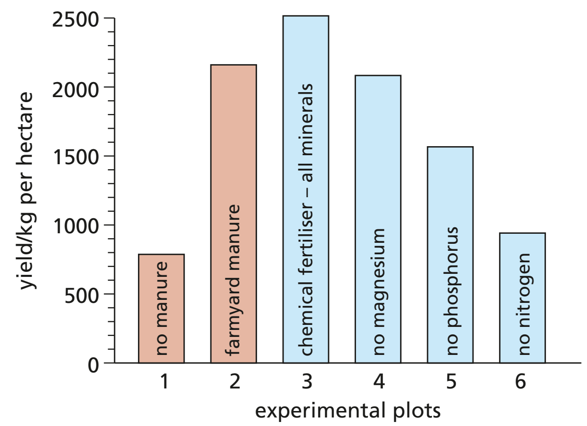


Figure 21.3 Average yearly wheat yields from 1852 to 1925, Broadbalk field, Rothamsted Experimental Station. Plot 1 received no manure or chemical fertiliser for 73 years. Plot 2 received an annual application of farmyard manure. Plot 3 received chemical fertiliser with all necessary minerals. Plots 4 to 6 received chemical fertiliser lacking one element.

Figure 21.4 Natural vegetation. Uncultivated land carries a wide variety of species.

Figure 21.2 Experimental plots of wheat. The rectangular plots have been treated with different fertilisers.

Figure 21.5 A monoculture. Only wheat is allowed to grow. All competing plants are destroyed.

Figure 21.6 Weed control by herbicide spraying. A young wheat crop is sprayed with herbicide to suppress weeds.

Figure 21.7 Effect of a herbicide spray. The crop has been sprayed except for a strip which the tractor driver missed.

The negative impact of monocultures

In a monoculture, every attempt is made to destroy organisms that feed on, compete with or infect the crop plant. So, the balanced life of a natural plant and animal community is displaced from farmland and left to survive only in small areas of woodland, heath or hedgerow. We have to decide on a balance between the amount of land to be used for agriculture and the amount of land left alone in order to keep a rich variety of wildlife on the Earth's surface.

Pesticides: insecticides and herbicides

Monocultures, with their dense populations of single species and repeated planting, are very susceptible to attack by insects or the spread of fungus diseases. To combat these threats, **pesticides** are used. A pesticide is a chemical that destroys agricultural pests or competitors.

For a monoculture to be maintained, plants that compete with the crop plant for root space, soil minerals and sunlight are killed by chemicals called **herbicides** (Figures 21.6 and 21.7). To destroy insects that eat and damage the plants, the crops are sprayed with **insecticides**.

The trouble with most pesticides is that they kill indiscriminately. Insecticides, for example, kill not only harmful insects but the harmless and beneficial ones, such as bees, which pollinate flowering plants, and ladybirds, which eat aphids.

In about 1960, a group of chemicals, including **aldrin** and **dieldrin**, were used as insecticides to kill wireworms and other insect pests in the soil. However, aldrin was found to reduce the number of species of soil animals in a pasture to half the original number (Figure 21.8). Dieldrin was also used as a seed dressing. If seeds were dipped in the chemical before planting, it prevented certain insects from attacking the seedlings. This was thought to be better than spraying the soil with dieldrin, which would have killed all the insects in the soil. Unfortunately pigeons, rooks, pheasants and partridges dug up and ate so much of the seed that the dieldrin poisoned them. Thousands of these birds were poisoned and, because they were part of a food web, birds of prey and foxes, which fed on them, were also killed. The use of dieldrin and aldrin was restricted in 1981 and banned in 1992.

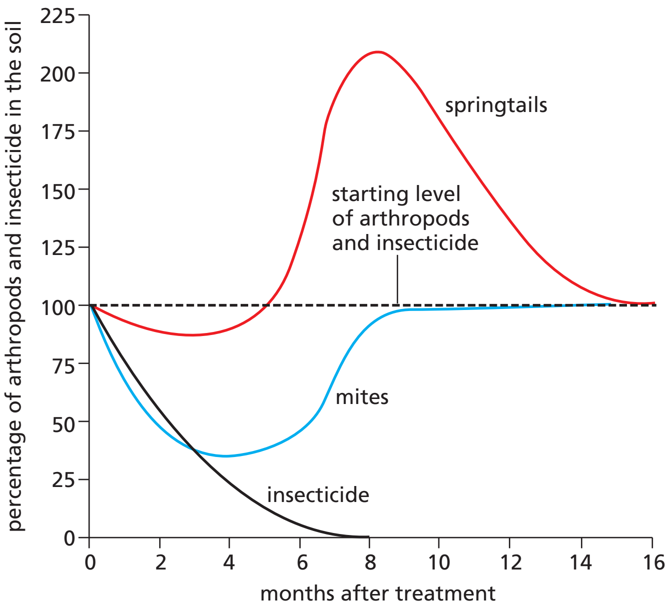


Figure 21.8 The effect of insecticide on some soil organisms

One alternative to pesticides is the use of biological control, though this also is not without its drawbacks unless it is thoroughly researched and tested. It may involve the introduction of foreign species, which could interfere with food chains and webs (see Chapter 19).

Selective breeding

An important part of any breeding programme is the selection of the desired varieties. The largest fruit on a tomato plant might be picked and its seeds planted next year. In the next generation, once again only seeds from the largest tomatoes are planted. Eventually it is possible to produce a true-breeding variety of tomato plant that forms large fruits. Figure 18.25 shows the result of such selective breeding for different characteristics. The same technique can be used for selecting other desirable qualities, such as flavour and disease resistance.

Similar principles can be applied to farm animals. Desirable characteristics, such as high milk yield and resistance to disease, may be combined. Stock-breeders will select calves from cows that give large quantities of milk. These calves will be used as breeding stock to build a herd of high yielders. A characteristic such as milk yield is probably under the control of many genes. At each stage of selective breeding the farmer, in effect, is keeping the beneficial genes and discarding the less useful genes from his or her animals.

Selective breeding in farm stock can be slow and expensive because the animals often have small numbers of offspring and breed only once a year.

One of the drawbacks of selective breeding is that the whole set of genes is transferred. As well as the desirable genes, there may be genes which, in a homozygous condition, would be harmful. It is known that artificial selection repeated over a large number of generations tends to reduce the fitness of the new variety (Chapter 18).

A long-term disadvantage of selective breeding is the loss of variability. By eliminating all the offspring who do not bear the desired characteristics, many genes are lost from the population. At some future date, when new combinations of genes are sought, some of the potentially useful ones may no longer be available.

In attempting to introduce, in plants, characteristics such as salt tolerance or resistance to disease or drought, the plant breeder goes back to wild varieties, as shown in Figure 18.26. However, with the current rate of extinction, this source of genetic material is diminishing.

In the natural world, reduction of variability could lead to local extinction if the population was unable to adapt, by natural selection, to changing conditions.

The negative impacts of intensive livestock production

Intensive livestock production is also known as 'factory farming'. Chickens (Figure 19.13) and calves are often reared in large sheds instead of in open fields. Their urine and faeces are washed out of the sheds with water forming 'slurry'. If this slurry gets into streams and rivers it supplies an excess of nitrates and phosphates for the microscopic algae. This starts a chain of events, which can lead to **eutrophication** of the water system (see later in this chapter).

Overgrazing can result if too many animals are kept on a pasture. They eat the grass down almost to the roots, and their hooves trample the surface soil into a hard layer. As a result, the rainwater will not penetrate the soil so it runs off the surface, carrying the soil with it. The soil becomes eroded.

The problems of world food supplies

There is not always enough food available in a country to feed the people living there. A severe food shortage can lead to famine. Food may have to be brought in (imported). Fresh food can have a limited storage life, so it needs to be transported quickly or treated to prevent it going rotten. Methods to increase the life of food include transport in chilled containers, or picking the produce before it is ripe. When it has reached its destination, it is exposed to chemicals such as plant auxins to bring on the ripening process. The use of aeroplanes to transport food is very expensive. The redistribution of food from first world countries to a poorer one can have a detrimental effect on that country's local economy by reducing the value of food grown by local farmers. Some food grown by countries with large debts may be exported as cash crops, even though the local people desperately need the food.

Other problems that can result in famine include:

- climate change and natural disasters such as flooding (caused by excessive rainfall or tsunamis) or drought; waterlogged soil can become infertile due to the activities of denitrifying bacteria, which break down nitrates
- pollution
- shortage of water through its use for other purposes, the diversion of rivers, building dams to provide hydroelectricity
- eating next year's seeds through desperation for food
- poor soil, lack of inorganic ions or fertiliser
- desertification due to soil erosion as a result of deforestation
- lack of money to buy seeds, fertiliser, pesticides or machinery
- war, which can make it too dangerous to farm, or which removes labour
- urbanisation (building on farmland); the development of towns and cities makes less and less land available for farmland
- an increasing population
- pest damage or disease
- poor education of farmers and outmoded farming practices
- the destruction of forests, so there is nothing to hunt and no food to collect
- use of farmland to grow cash crops, or plants for biofuel.

Habitat destruction

Removal of habitats

Farmland is not a natural habitat but, at one time, hedgerows, hay meadows and stubble fields were important habitats for plants and animals. Hay meadows and hedgerows supported a wide range of wild plants as well as providing feeding and nesting sites for birds and animals.

Intensive agriculture has destroyed many of these habitats; hedges have been grubbed out (see Figure 21.1) to make fields larger, a monoculture of silage grasses (Figure 21.9) has replaced the mixed population of a hay meadow (Figure 21.10) and planting of winter wheat has denied animals access to stubble fields in autumn. As a result, populations of butterflies, flowers and birds such as skylarks, grey partridges, corn buntings and tree sparrows have crashed.

Recent legislation now prohibits the removal of hedgerows without approval from the local authority but the only hedges protected in this way are those deemed to be 'important' because of species diversity or historical significance.

In Britain, the **Farming and Wildlife Advisory Group** (**FWAG**) can advise farmers how to manage their land in ways that encourage wildlife. This includes, for example, leaving strips of uncultivated land around the margins of fields or planting new hedgerows. Even strips of wild grasses and flowers between fields significantly increase the population of beneficial insects.

The development of towns and cities (**urbanisation**) makes a great demand on land, destroying natural habitats. In addition, the crowding of growing populations into towns leads to problems of waste disposal. The sewage and domestic waste from a town of several thousand people can cause disease and pollution in the absence of effective means of disposal, damaging surrounding habitats.

Extraction of natural resources

An increasing population and greater demands on modern technology means we need more raw materials for the manufacturing industry and greater energy supplies.

Fossil fuels such as coal can be mined, but this can permanently damage habitats, partly due to the process of extraction, but also due to dumping of the rock extracted in spoil heaps. Some methods of coal extraction involve scraping off existing soil from the surface of the land. Spoil heaps created from waste rock can contain toxic metals, which prevent re-colonisation of the land. Open-pit mining puts demands on local water sources, affecting habitats in lakes and rivers. Water can become contaminated with toxic metals from the mining site, damaging aquatic habitats.

Oil spillages around oil wells are extremely toxic. Once the oil seeps into the soil and water systems, habitats are destroyed (Figure 21.11)

Figure 21.9 Grass for silage. There is no variety of plant life and, therefore, an impoverished population of insects and other animals.

Figure 21.10 The variety of wild flowers in a traditional hay meadow will attract butterflies and other insects.

Figure 21.11 Habitat destruction caused by an oil spillage in Nigeria

Mining for raw materials such as gold, iron aluminium and silicon leaves huge scars in the landscape and destroys large areas of natural habitat (Figure 21.12). The extraction of sand and gravel also leaves large pits that prevent previous habitats redeveloping.

Figure 21.12 Open-pit gold mine in New Zealand

In response to this increased human activity, in 1982 the United Nations developed the **World Charter for Nature**. This was followed in 1990 by **The World Ethic of Sustainability**, created by the World Wide Fund for Nature (WWF), the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme (UNEP). Included in this charter were habitat conservation and the need to protect natural resources from depletion.

Marine pollution

Marine habitats around the world are becoming contaminated with human debris. This includes untreated sewage, agricultural fertilisers and pesticides. Oil spills still cause problems, but this source of marine pollution is gradually reducing. Plastics are a huge problem: many are non-biodegradable so they persist in the environment. Others form micro-particles as they break down and these are mistaken by marine organisms for food and are indigestible. They stay in the stomach, causing sickness, or prevent the gills from working efficiently. Where fertilisers and sewage enter the marine environment, 'dead zones' develop where there is insufficient oxygen to sustain life. This destroys habitats (see next section).

Oil spills wash up on the intertidal zone, killing the seaweeds that provide nutrients for food chains. Filter-feeding animals such as barnacles and some species of mollusc die from taking in the oil (see Figure 1.8).

Any form of habitat destruction by humans, even where a single species is wiped out, can have an impact on food chains and food webs because other organisms will use that species as a food source, or their numbers will be controlled through its predation.

Deforestation

The removal of large numbers of trees results in habitat destruction on a massive scale.

- Animals living in the forest lose their homes and sources of food; species of plant become extinct as the land is used for other purposes such as agriculture, mining, housing and roads.
- Soil erosion is more likely to happen as there are no roots to hold the soil in place. The soil can end up in rivers and lakes, destroying habitats there.
- Flooding becomes more frequent as there is no soil to absorb and hold rainwater. Plant roots rot and animals drown, destroying food chains and webs.
- Carbon dioxide builds up in the atmosphere as there are fewer trees to photosynthesise, increasing global warming. Climate change affects habitats.

The undesirable effects of deforestation on the environment

Forests have a profound effect on climate, water supply and soil maintenance. They have been described as environmental buffers. For example, they intercept heavy rainfall and release the water steadily and slowly to the soil beneath and to the streams and rivers that start in or flow through them. The tree roots hold the soil in place.

At present, we are destroying forests, particularly tropical forests, at a rapid rate (1) for their timber, (2) to make way for agriculture, roads (Figure 21.13) and settlements, and (3) for firewood. The Food and Agriculture Organisation, run by the United Nations, reported that the overall tropical deforestation rates in the decade up to 2010 were 8.5% higher than during the 1990s. At the current rate of destruction, it is estimated that all tropical rainforests will have disappeared in the next 75 years.

Removal of forests allows soil erosion, silting up of lakes and rivers, floods and the loss for ever of thousands of species of animals and plants.

Trees can grow on hillsides even when the soil layer is quite thin. When the trees are cut down and the soil is ploughed, there is less protection from the wind and rain. Heavy rainfall washes the soil off the hillsides into the rivers. The hillsides are left bare and useless and the rivers become choked up with mud and silt, which can cause floods (Figures 21.14 and 21.15). For example, Argentina spends 10 million dollars a year on dredging silt from the River Plate estuary to keep the port of Buenos Aires open to shipping. It has been found that 80% of this sediment comes from a deforested and overgrazed region 1800 km upstream, which represents only 4% of the river's total catchment area. Similar sedimentation has halved the lives of reservoirs, hydroelectric schemes and irrigation programmes. The disastrous floods in India and Bangladesh in recent years may be attributed largely to deforestation.

Figure 21.13 Cutting a road through a tropical rainforest. The road not only destroys the natural vegetation, it also opens up the forest to further exploitation.

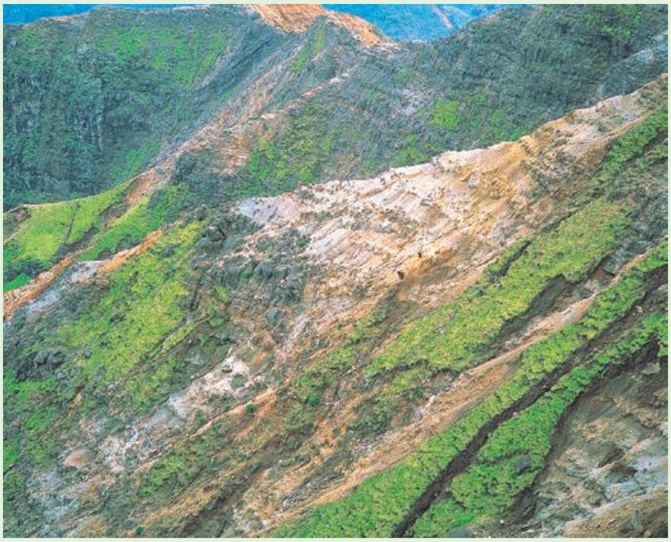


Figure 21.14 Soil erosion. Removal of forest trees from steeply sloping ground has allowed the rain to wash away the topsoil.

The soil of tropical forests is usually very poor in nutrients. Most of the organic matter is in the leafy canopy of the tree tops. For a year or two after felling and burning, the forest soil yields good crops but the nutrients are soon depleted and the soil eroded. The agricultural benefit from cutting down forests is very short-lived, and the forest does not recover even if the impoverished land is abandoned.

Forests and climate

About half the rain that falls in tropical forests comes from the transpiration of the trees themselves. The clouds that form from this transpired water help to reflect sunlight and so keep the region relatively cool and humid. When areas of forest are cleared, this source of rain is removed, cloud cover is reduced and the local climate changes quite dramatically. The temperature range from day to night is more extreme and the rainfall diminishes.

In North Eastern Brazil, for example, an area which was once rainforest is now an arid wasteland. If more than 60% of a forest is cleared, it may cause irreversible changes in the climate of the whole region. This could turn the region into an unproductive desert.

Removal of trees on such a large scale also reduces the amount of carbon dioxide removed from the atmosphere in the process of photosynthesis (see 'Nutrient cycles', Chapter 19, and 'Photosynthesis', Chapter 6). Most scientists agree that the build-up of CO_2 in the atmosphere contributes to global warming.

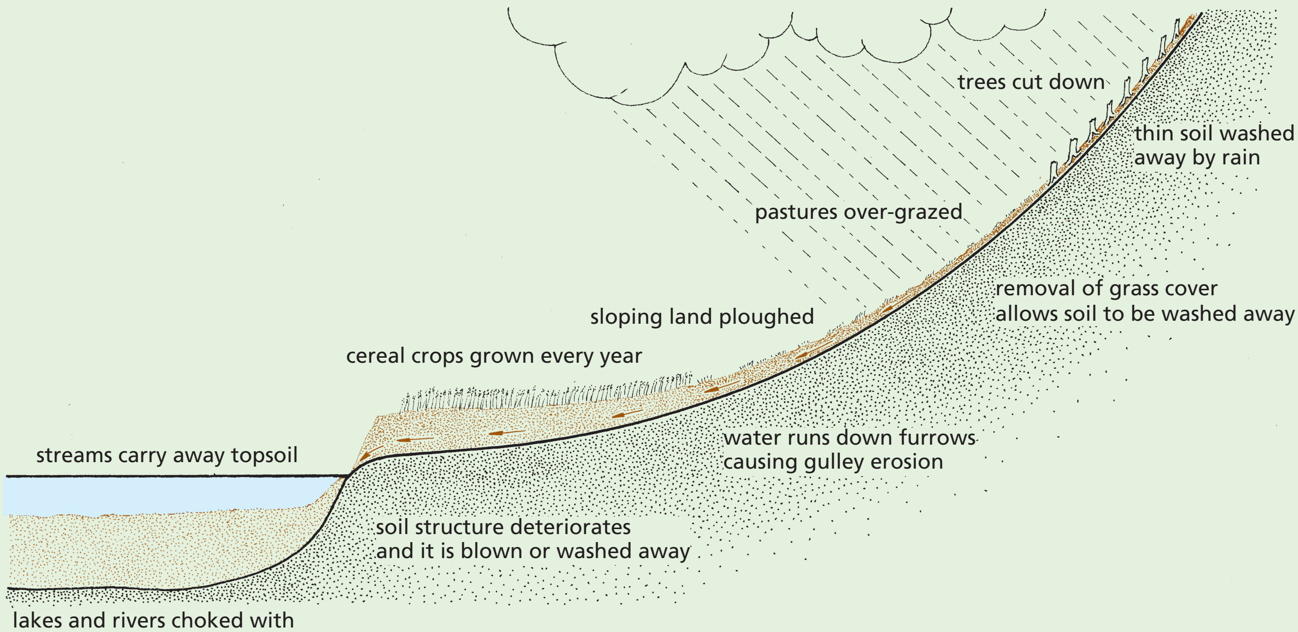


Figure 21.15 The causes of soil erosion

Forests and biodiversity

One of the most characteristic features of tropical rainforests is the enormous diversity of species they contain. In Britain, a forest or wood may consist of only one or two species of tree such as oak, ash, beech or pine. In tropical forests there are many more species and they are widely dispersed throughout the habitat. It follows that there is also a wide diversity of animals that live in such habitats. In fact, it has been estimated that half of the world's 10 million species live in tropical forests.

Destruction of tropical forest, therefore, destroys a large number of different species, driving many of them to the verge of extinction, and also drives out the indigenous populations of humans. In addition, we may be depriving ourselves of many valuable sources of chemical compounds that the plants and animals produce. The US National Cancer Institute has identified 3000 plants having products active against cancer cells and 70% of them come from rainforests (Figure 21.16).

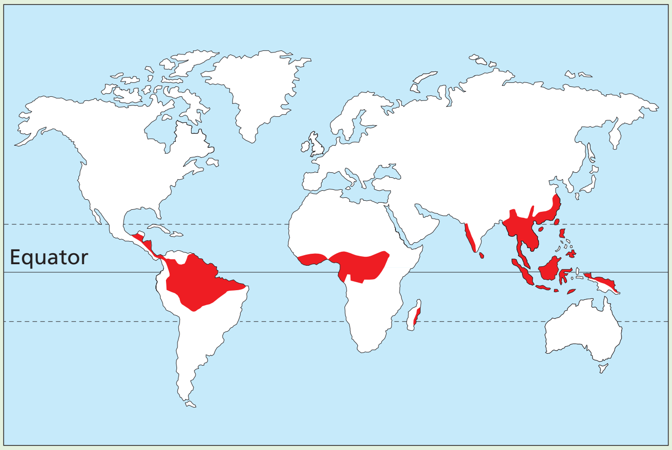


Figure 21.16 The world's rainforests

Pollution

Insecticides

The effects of the insecticides aldrin and dieldrin were discussed earlier in this chapter. Most insecticide pollution is as a result of their use in agriculture. However, one pesticide, called DDT, was used to control the spread of malaria by killing mosquitos, which carry the protoctist parasites that cause the disease. Unfortunately, DDT remains in the environment after it has been sprayed and can be absorbed in sub-lethal doses by microscopic organisms. Hence, it can enter food chains and accumulate as it moves up them.

The concentration of insecticide often increases as it passes along a food chain (Figure 21.17). Clear Lake in California was sprayed with DDT to kill gnat larvae. The insecticide made only a weak solution of 0.015 parts per million (ppm) in the lake water. The microscopic plants and animals that fed in the lake water built up concentrations of about 5 ppm in their bodies. The small fish that fed on the microscopic animals had 10 ppm. The small fish were eaten by larger fish, which in turn were eaten by birds called grebes. The grebes were found to have 1600 ppm of DDT in their body fat and this high concentration killed large numbers of them.

Larger scale pollution of water by insecticides, for instance by leakage from storage containers, may kill aquatic insects, destroying one or more levels in a food chain or food web, with serious consequences to the ecosystem.

A build-up of pesticides can also occur in food chains on land. In the 1950s in the USA, DDT was sprayed on to elm trees to try and control the beetle that spread Dutch elm disease. The fallen leaves, contaminated with DDT, were eaten by earthworms. Because each worm ate many leaves, the DDT concentration in their bodies was increased ten times. When birds ate a large number of worms, the concentration of DDT in the birds' bodies reached lethal proportions and there was a 30–90% mortality among robins and other song birds in the cities.

Even if DDT did not kill the birds, it caused them to lay eggs with thin shells. The eggs broke easily and fewer chicks were raised. In Britain, the numbers of peregrine falcons and sparrow hawks declined drastically between 1955 and 1965. These birds are at the top of a food web and so accumulate very high doses of the pesticides that are present in their prey, such as pigeons. After the use of DDT was restricted, the population of peregrines and sparrow hawks started to recover.

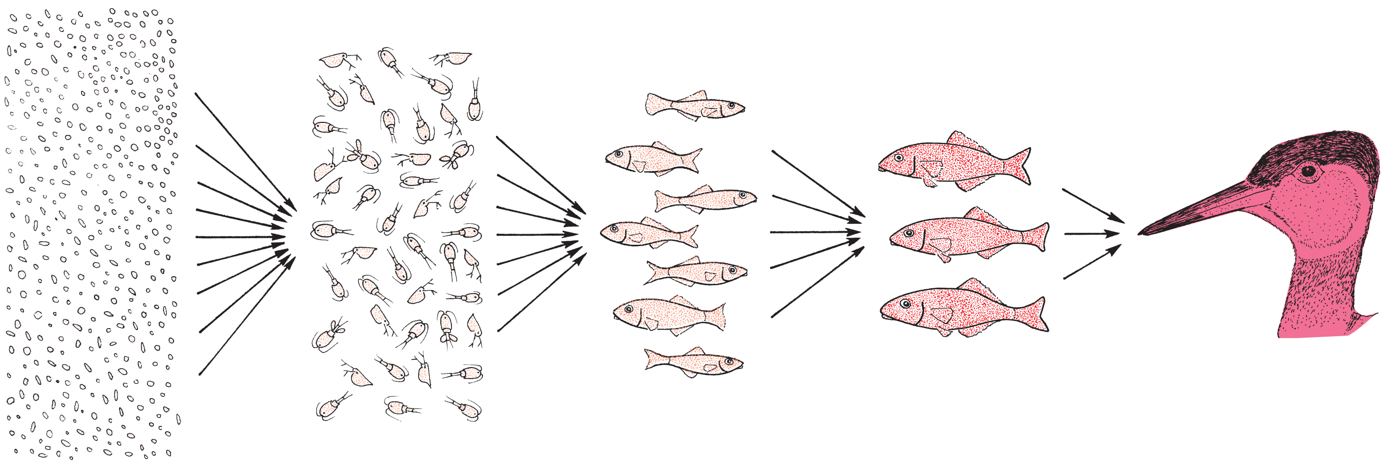


Figure 21.17 Pesticides may become more concentrated as they move along a food chain. The intensity of colour represents the concentration of DDT.

These new insecticides had been thoroughly tested in the laboratory to show that they were harmless to humans and other animals when used in low concentrations. It had not been foreseen that the insecticides would become more and more concentrated as they passed along the food chain.

Insecticides like this are called **persistent** because they last a long time without breaking down. This makes them good insecticides but they also persist for a long time in the soil, in rivers, lakes and the bodies of animals, including humans. This is a serious disadvantage.

Herbicides

Herbicides are used by farmers to control plants (usually referred to as weeds) that compete with crop plants for nutrients, water and light (see Figure 21.7). If the weeds are not removed, crop productivity is reduced. However, if the herbicides do not break down straight away, they can leach from farmland into water systems such as rivers and lakes, where they can kill aquatic plants, removing the producers from food chains. Herbivores lose their food source and die or migrate. Carnivorous animals are then affected as well.

Leakage or dumping of persistent herbicides into the sea can have a similar effect on marine food chains.

Herbicides tend to be non-specific: they kill any broadleaved plants they come into contact with or are absorbed by. If herbicides are sprayed indiscriminately, they may blow onto surrounding land and kill plants other than the weeds in the crop being treated. This can put rare species of wild flowers at risk.

Nuclear fall-out

This can be the result of a leak from a nuclear power station, or from a nuclear explosion. Radioactive particles are carried by the wind or water and gradually settle in the environment. If the radiation has a long **half-life**, it remains in the environment and is absorbed by living organisms. The radioactive material bioaccumulates in food chains and can cause cancer in top carnivores.

Probably the worst nuclear accident in history happened at Chernobyl in Russia in April 1986. One of the reactor vessels exploded and the resulting fire produced a cloud of radioactive fallout, which was carried by prevailing winds over other parts of the Soviet Union and Europe. The predicted death toll, from direct exposure to the radiation and indirectly from the fallout, is estimated to be at least 4000 people (and possibly much higher), with many others suffering from birth defects or cancers associated with exposure to radiation. The fall-out contaminated the soil it fell on and was absorbed by plants, which were grazed by animals. Farmers in the Lake District in England were still banned from selling sheep for meat until June 2012, 26 years after the contamination of land there first happened.

Another major nuclear disaster happened at the Fukushima nuclear power plant in Japan in March 2011 (Figure 21.18). The plant was hit by a powerful tsunami, caused by an earthquake. A plume of radioactive material was carried from the site by the wind and came down onto the land, forming a scar like a teardrop over 30 kilometres wide. The sea around the power plant is heavily contaminated by radiation. This is absorbed into fish bones, making the animals unfit for consumption.

Figure 21.18 Fukushima nuclear power plant, destroyed by a powerful tsunami and fire

Chemical waste

Many industrial processes produce poisonous waste products. Electroplating, for example, produces waste containing copper and cyanide. If these chemicals are released into rivers they poison the animals and plants and could poison humans who drink the water. It is estimated that the River Trent receives 850 tonnes of zinc, 4000 tonnes of nickel and 300 tonnes of copper each year from industrial processes.

Any factory getting rid of its effluent into water systems risks damaging the environment (Figure 21.19). Some detergents contain a lot of phosphate. This is not removed by sewage treatment and is discharged into rivers. The large amount of phosphate encourages growth of microscopic plants (algae).

Figure 21.19 River pollution. The river is badly polluted by the effluent from a paper mill.

In 1971, 45 people in Minamata Bay in Japan died and 120 were seriously ill as a result of mercury poisoning. It was found that a factory had been discharging a compound of mercury into the bay as part of its waste. Although the mercury concentration in the sea was very low, its concentration was increased as it passed through the food chain (see Figure 21.17). By the time it reached the people of Minamata Bay in the fish and other sea food that formed a large part of their diet, it was concentrated enough to cause brain damage, deformity and death.

High levels of mercury have also been detected in the Baltic Sea and in the Great Lakes of North America.

Oil pollution of the sea has become a familiar event. In 1989, a tanker called the *Exxon Valdez* ran on to Bligh Reef in Prince William Sound, Alaska, and 11 million gallons of crude oil spilled into the sea. Around 400 000 sea birds were killed by the oil (Figure 21.20) and the populations of killer whales, sea otters and harbour seals among others, were badly affected. The hot water high-pressure hosing techniques and chemicals used to clean up the shoreline killed many more birds and sea creatures living on the coast. Since 1989, there have continued to be major spillages of crude oil from tankers and off-shore oil wells.

Discarded rubbish

The development of towns and cities, and the crowding of growing populations into them, leads to problems of waste disposal. The domestic waste from a town of several thousand people can cause disease and pollution in the absence of effective means of disposal. Much ends up in landfill sites, taking up valuable space, polluting the ground and attracting vermin and insects, which can spread disease. Most consumable items come in packaging, which, if not recycled, ends up in landfill sites or is burned, causing air pollution. Discarded rubbish that ends up in the sea can cause severe problems for marine animals.

Figure 21.20 Oil pollution. Oiled sea birds like this long-tailed duck cannot fly to reach their feeding grounds. They also poison themselves by trying to clean the oil from their feathers.

Sewage

Diseases like typhoid and cholera are caused by certain bacteria when they get into the human intestine. The faeces passed by people suffering from these diseases will contain the harmful bacteria. If the bacteria get into drinking water they may spread the disease to hundreds of other people. For this reason, among others, untreated sewage must not be emptied into rivers. It is treated at the sewage works so that all the solids are removed. The human waste is broken down by bacteria and made harmless (free from harmful bacteria and poisonous chemicals), but the breakdown products include phosphates and nitrates. When the water from the sewage treatment is discharged into rivers it contains large quantities of phosphate and nitrate, which allow the microscopic plant life to grow very rapidly (Figure 21.21).

Figure 21.21 Growth of algae in a lake. Abundant nitrate and phosphate from treated sewage and from farmland make this growth possible.

Fertilisers

When nitrates and phosphates from farmland and sewage escape into water they cause excessive growth of microscopic green plants. This may result in a serious oxygen shortage in the water, resulting in the death of aquatic animals – a process called **eutrophication**.

Eutrophication

Nitrates and phosphates are present from a number of sources, including untreated sewage, detergents from manufacturing and washing processes, arable farming and factory farming.

If these nitrates or phosphates enter a water system, they become available for algae (aquatic plants) to absorb. The plants need these nutrients to grow. More nutrients result in faster growth (Figure 21.21). As the plants die, some through lack of light because of overcrowding, aerobic bacteria decompose them and respire, taking oxygen out of the water. As oxygen levels drop, animals such as fish cannot breathe, so they die and the whole ecosystem is destroyed (Figure 21.22).

Figure 21.22 Fish killed by pollution. The water may look clear but is so short of oxygen that the fish have died from suffocation.

Figure 21.23 shows this sequence of events as a flow chart.

nitrates or phosphates from raw sewage, fertilisers or other sources enter a water system (river or lake)

↓

algae absorb the nutrients and grow rapidly (called an algal bloom)

↓

algae form a blanket on the surface of the water, blocking light from the reaching algae below

↓

algae die without light

↓

bacteria decompose the dead algae, using up the oxygen in the water for respiration

↓

animals in the water die through lack of oxygen

Figure 21.23 The sequence of events leading to eutrophication

The greenhouse effect and global warming

Levels of carbon dioxide in the atmosphere are influenced by natural processes and by human activities. Processes that change the equilibrium (balance) include:

- cutting down forests (deforestation) – less photosynthesis
- combustion of fossil fuels (coal, oil and gas)
- increasing numbers of animals (including humans) – they all respire.

An increase in levels of carbon dioxide in the atmosphere is thought to contribute to global warming. Carbon dioxide forms a layer in the atmosphere, which traps heat radiation from the Sun.

Methane also acts as a greenhouse gas. Its levels in the atmosphere have more than doubled over the past 200 years and its effects on global warming are much greater than carbon dioxide. It is produced by the decay of organic matter in anaerobic conditions, such as in wet rice fields and in the stomachs of animals, e.g. cattle and termites. It is also released from the ground during the extraction of oil and coal.

The build-up of greenhouse gases causes a gradual increase in the atmospheric temperature, known as the **enhanced greenhouse effect**. This can:

- melt polar ice caps, causing flooding of low-lying land
- change weather conditions in some countries, increasing flooding or reducing rainfall – changing arable (farm) land to desert; extreme weather conditions become more common
- cause the extinction of some species that cannot survive in raised temperatures.

Eutrophication

In Chapter 6 it was explained that plants need a supply of nitrates for making their proteins. They also need a source of phosphates for many chemical reactions in their cells. The rate at which plants grow is often limited by how much nitrate and phosphate they can obtain. In recent years, the amount of nitrate and phosphate in our rivers and lakes has been greatly increased. This leads to an accelerated process of eutrophication.

Eutrophication is the enrichment of natural waters with nutrients that allow the water to support an increasing amount of plant life. This process takes place naturally in many inland waters but usually very slowly. The excessive enrichment that results from human activities leads to an overgrowth of microscopic algae (Figure 21.21). These aquatic algae are at the bottom of the food chain. The extra nitrates and phosphates from the processes listed on page 329 enable them to increase so rapidly that they cannot be kept in check by the microscopic animals which normally eat them. So they die and fall to the bottom of the river or lake. Here, their bodies are broken down by bacteria. The bacteria need oxygen to carry out this breakdown and the oxygen is taken from the water (Figure 21.24). So much oxygen is taken that the water becomes deoxygenated and can no longer support animal life. Fish and other organisms die from suffocation (Figure 21.22).

The following processes are the main causes of eutrophication.

Discharge of treated sewage

In a sewage treatment plant, human waste is broken down by bacteria and made harmless, but the breakdown products include phosphates and nitrates. When the water from the sewage treatment is discharged into rivers it contains large quantities of phosphates and nitrates, which allow the microscopic plant life to grow very rapidly (Figure 21.21).

Use of detergents

Some detergents contain a lot of phosphate. This is not removed by sewage treatment and is discharged into rivers. The large amount of phosphates encourages growth of microscopic plants (algae).

Arable farming

Since the Second World War, more and more grassland has been ploughed up in order to grow arable crops such as wheat and barley. When soil is exposed in this way, the bacteria, aided by the extra oxygen and water, produce soluble nitrates, which are washed into streams and rivers where they promote the growth of algae. If the nitrates reach underground water stores they may increase the nitrate in drinking water to levels considered 'unsafe' for babies.

Some people think that it is excessive use of artificial fertilisers that causes this pollution but there is not much evidence for this.

'Factory farming'

Chickens and calves are often reared in large sheds instead of in open fields. Their urine and faeces are washed out of the sheds with water forming 'slurry'. If this slurry gets into streams and rivers it supplies an excess of nitrates and phosphates for the microscopic algae.

The degree of pollution of river water is often measured by its **biochemical oxygen demand** (**BOD**). This is the amount of oxygen used up by a sample of water in a fixed period of time. The higher the BOD, the more polluted the water is likely to be.

It is possible to reduce eutrophication by using:

- detergents with less phosphates
- agricultural fertilisers that do not dissolve so easily
- animal wastes on the land instead of letting them reach rivers.

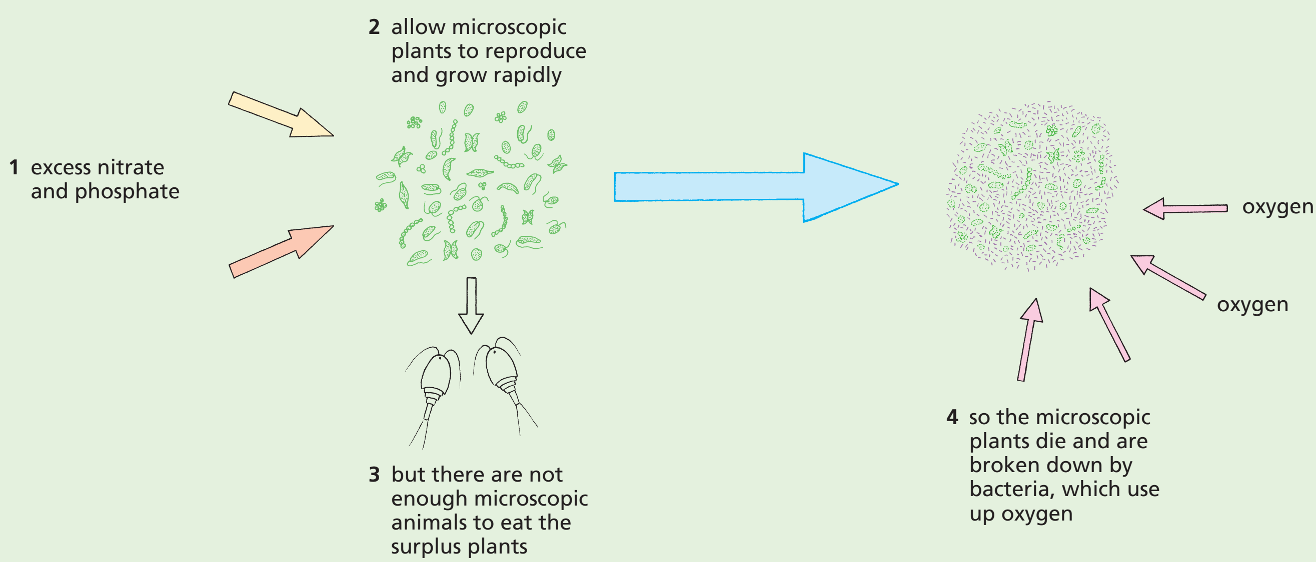


Figure 21.24 Processes leading to eutrophication

Plastics and the environment

Plastics that are non-biodegradable are not broken down by decomposers when dumped in landfill sites or left as litter. This means that they remain in the environment, taking up valuable space or causing visual pollution. Discarded plastic bottles can trap small animals; nylon fishing lines and nets can trap birds and mammals such as seals and dolphins. As the plastics in water gradually deteriorate, they fragment into tiny pieces, which are eaten by fish and birds, making them ill. When plastic is burned, it can release toxic gases.

Plastic bags are a big problem, taking up a lot of space in landfill sites. In 2002, the Republic of Ireland introduced a plastic bag fee, called a PlasTax, to try to control the problem. It had a dramatic effect, cutting the use of single-use bags from 1.2 billion to 230 million a year and reducing the litter problem that plastic bags create. Revenue raised from the fee is used to support environmental projects.

Air pollution

Some factories (Figure 21.25) and most motor vehicles release poisonous substances into the air. Factories produce smoke and sulfur dioxide; cars produce lead compounds, carbon monoxide and the oxides of nitrogen, which lead to smog (Figure 21.26) and acid rain (Figure 21.27).

Figure 21.26 Photochemical 'smog' over a city

Figure 21.25 Air pollution by industry. Tall chimneys keep pollution away from the immediate surroundings but the atmosphere is still polluted.

Figure 21.27 Effects of acid rain on conifers in the Black Forest, Germany

Sulfur dioxide and oxides of nitrogen

Coal and oil contain sulfur. When these fuels are burned, they release sulfur dioxide (SO_2) into the air (Figure 21.28). Although the tall chimneys of factories (Figure 21.25) send smoke and sulfur dioxide high into the air, the sulfur dioxide dissolves in rainwater and forms an acid. When this acid falls on buildings, it slowly dissolves the limestone and mortar. When it falls on plants, it reduces their growth and damages their leaves.

This form of pollution has been going on for many years and is getting worse. In North America, Scandinavia and Scotland, forests are being destroyed (Figure 21.27) and fish are dying in lakes, at least partly as a result of acid rain.

Oxides of nitrogen from power stations and vehicle exhausts also contribute to atmospheric pollution and acid rain. The nitrogen oxides dissolve in rain drops and form nitric acid.

Oxides of nitrogen also take part in reactions with other atmospheric pollutants and produce ozone. It may be the ozone and the nitrogen oxides that are largely responsible for the damage observed in forests.

One effect of acid rain is that it dissolves out the aluminium salts in the soil. These salts eventually reach toxic levels in streams and lakes.

There is still some argument about the source of the acid gases that produce acid rain. For example, a large proportion of the sulfur dioxide in the atmosphere comes from the natural activities of certain marine algae. These microscopic 'plants' produce the gas dimethylsulfide which is oxidised to sulfur dioxide in the air.

Nevertheless, there is considerable circumstantial evidence that industrial activities in Britain, America and Central and Eastern Europe add large amounts of extra sulfur dioxide and nitrogen oxides to the atmosphere.

Control of air pollution

The Clean Air Acts of 1956 and 1968

These acts designated certain city areas as 'smokeless zones' in Britain. The use of coal for domestic heating was prohibited and factories were not allowed to emit black smoke. This was effective in abolishing dense fogs in cities but did not stop the discharge of sulfur dioxide and nitrogen oxides in the country as a whole.

Reduction of acid gases

The concern over the damaging effects of acid rain has led many countries to press for regulations to reduce emissions of sulfur dioxide and nitrogen oxides.

Reduction of sulfur dioxide can be achieved either by fitting desulfurisation plants to power stations or by changing the fuel or the way it is burnt. In 1986, Britain decided to fit desulfurisation plants to three of its major power stations, but also agreed to a United Nations protocol to reduce sulfur dioxide emissions to 50% of 1980 levels by the year 2000,

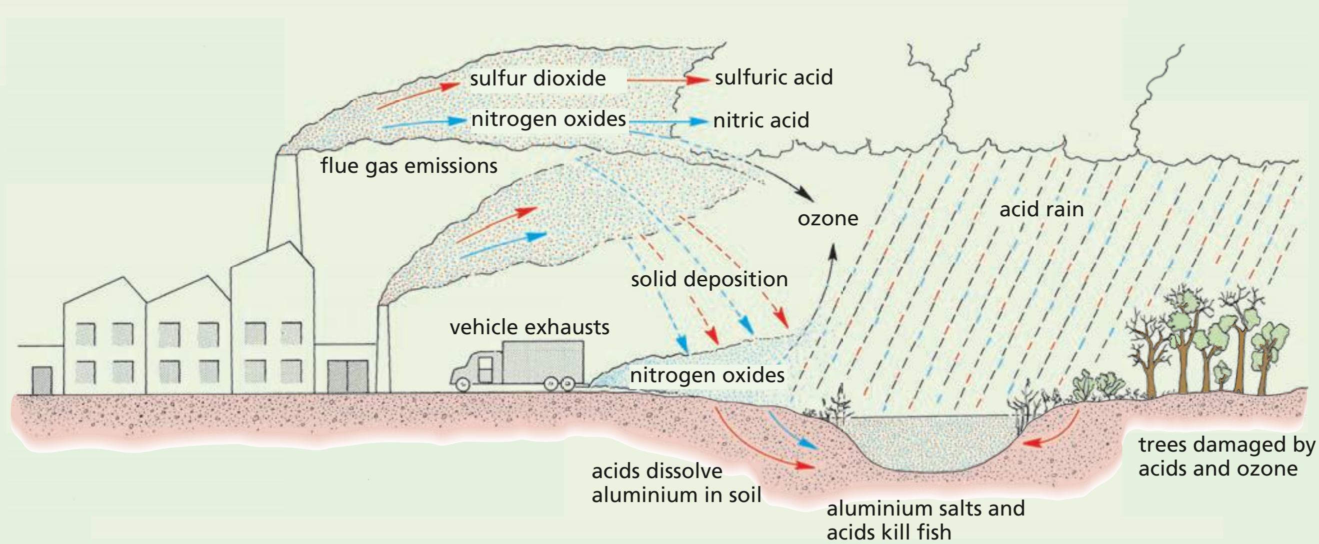


Figure 21.28 Acid rain in Britain. The pollution comes from British factories, power stations, homes and vehicles. Most emissions start as dry gases and are converted slowly to dilute sulfuric and nitric acids.

and to 20% by 2010. This was to be achieved largely by changing from coal-fired to gas-fired power stations.

Reduction of vehicle emissions

Oxides of nitrogen come, almost equally, from industry and from motor vehicles (Figure 21.28). Flue gases from industry can be treated to remove most of the nitrogen oxides. Vehicles can have **catalytic converters** fitted to their exhaust systems. These converters remove most of the nitrogen oxides, carbon monoxide and unburned hydrocarbons. They add £200–600 to the cost of a car and will work only if lead-free petrol is used, because lead blocks the action of the catalyst.

Another solution is to redesign car engines to burn petrol at lower temperatures (**'lean burn'** engines). These emit less nitrogen oxide but just as much carbon monoxide and hydrocarbons as normal engines.

In the long term, it may be possible to use fuels such as alcohol or hydrogen, which do not produce so many pollutants.

The European Union has set limits on exhaust emissions. From 1989, new cars over 2 litres had to have catalytic converters and from 1993 smaller cars had to fit them as well.

Regulations introduced in 1995 should cut emissions of particulates by 75% and nitrogen oxides by 50%. These reductions will have less effect if the volume of traffic continues to increase. Significant reduction of pollutants is more likely if the number of vehicles is stabilised and road freight is reduced.

Protecting the ozone layer

The appearance of 'ozone holes' in the Antarctic and Arctic, and the thinning of the ozone layer elsewhere, spurred countries to get together and agree to reduce the production and use of CFCs (chlorofluorocarbons) and other ozone-damaging chemicals.

1987 saw the first Montreal protocol, which set targets for the reduction and phasing out of these chemicals. In 1990, nearly 100 countries, including Britain, agreed to the next stage of the Montreal protocol, which committed them to reduce production of CFCs by 85% in 1994 and phase them out completely by 2000. Overall, the Montreal protocol has proved to be very successful: by 2012, the world had phased-out 98% of the ozone-depleting substances such as CFCs. However, the chemicals that were used to replace CFCs (HCFCs) are not as harmless as they were first thought to be, as they contribute to global warming.

The 'greenhouse effect' and global warming

The Earth's surface receives and absorbs radiant heat from the Sun. It re-radiates some of this heat back into space. The Sun's radiation is mainly in the form of short-wavelength energy and penetrates our atmosphere easily. The energy radiated back from the Earth is in the form of long wavelengths (infrared or IR), much of which is absorbed by the atmosphere. The atmosphere acts like the glass in a greenhouse. It lets in light and heat from the Sun but reduces the amount of heat that escapes (Figure 21.29).

If it were not for this 'greenhouse effect' of the atmosphere, the Earth's surface would probably be at −18 °C. The 'greenhouse effect', therefore, is entirely natural and desirable.

Not all the atmospheric gases are equally effective at absorbing IR radiation. Oxygen and nitrogen, for example, absorb little or none. The gases that absorb most IR radiation, in order of maximum absorption, are water vapour, carbon dioxide (CO_2), methane and atmospheric pollutants such as oxides of nitrogen and CFCs. Apart from water vapour, these gases are in very low concentrations in the atmosphere, but some of them are strong absorbers of IR radiation. It is assumed that if the concentration of any of these gases were to increase, the greenhouse effect would be enhanced and the Earth would get warmer.

In recent years, attention has focused principally on CO_2. If you look back at the carbon cycle in Chapter 19, you will see that the natural processes of photosynthesis, respiration and decay would be expected to keep the CO_2 concentration at a steady level. However, since the Industrial Revolution, we have been burning 'fossil fuels' derived from coal and petroleum and releasing extra CO_2 into the atmosphere. As a result, the concentration of CO_2 has increased from 0.029 to 0.039% since 1860. It is likely to go on increasing as we burn more and more

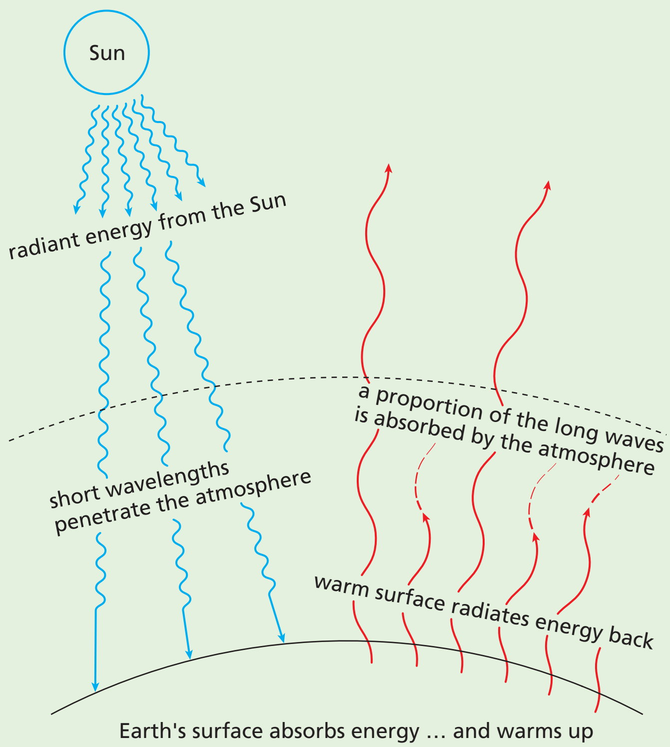


Figure 21.29 The 'greenhouse effect'

fossil fuel. According to NOAA data, CO_2 levels rose 2.67 parts per million in 2012, to 395 ppm. This was the second largest increase since 1959, when scientists first began measuring atmospheric CO_2 levels.

Although it is not possible to prove beyond all reasonable doubt that production of CO_2 and other 'greenhouse gases' is causing a rise in the Earth's temperature, i.e. global warming, the majority of scientists and climatologists agree that it is happening now and will get worse unless we take drastic action to reduce the output of these gases.

Predictions of the effects of global warming depend on computer models. But these depend on very complex and uncertain interactions of variables.

Changes in climate might increase cloud cover and this might reduce the heat reaching the Earth from the Sun. Oceanic plankton absorb a great deal of CO_2. Will the rate of absorption increase or will a warmer ocean absorb less of the gas? An increase in CO_2 should, theoretically, result in increased rates of photosynthesis, bringing the system back into balance.

None of these possibilities is known for certain. The worst scenario is that the climate and rainfall distribution will change, and disrupt the present pattern of world agriculture; the oceans will expand and the polar icecaps will melt, causing a rise in sea level; extremes of weather may produce droughts and food shortages.

An average of temperature records from around the world suggests that, since 1880, there has been a rise of 0.7–0.9 °C, most of it very recently (Figure 21.30), but this is too short a period from which to draw firm conclusions about long-term trends. If the warming trend continues, however, it could produce a rise in sea level of between 0.2 and 1.5 metres in the next 50–100 years.

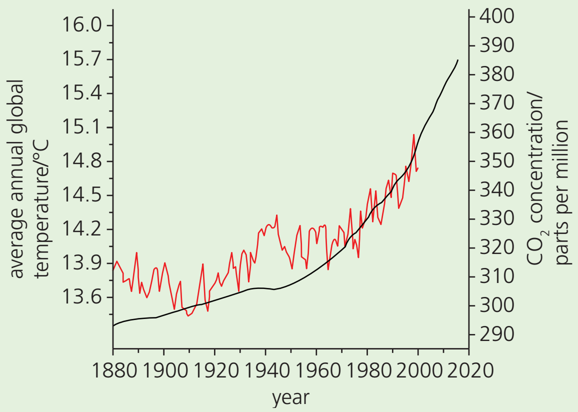


Figure 21.30 Annual average global temperatures and carbon dioxide levels since 1880

The first Kyoto Conference (Japan) in 1997 set targets for the industrialised countries to reduce CO_2 emissions by an average of 5.2% by 2010. Europe, as a whole, agreed to cuts of 8%, though this average allowed some countries to increase their emissions. The countries committed to the Kyoto convention, excluding the USA, eventually modified the targets, but agreed to make cuts of 4.2% on average for the period 2008–2012.

Britain planned to reduce emissions by 20% of 1990 levels by 2010 but really needed an overall cut of 60% to halt the progress of global warming. The big industrialised countries who contribute 80% of the greenhouse gases, particularly the USA, are opposed to measures that might interfere with their industries, claiming that global warming is not a proven fact.

The precautionary principle suggests that, even if global warming is not taking place, our supplies of fossil fuels will eventually run out and we need to develop alternative sources of energy now.

The generation of energy using fossil fuels is the biggest source of CO_2 released by humans into the atmosphere. The alternatives are nuclear power or methods such as wind farms and solar energy. The experiences of Chernobyl and Fukushima have made people around the world very wary of the nuclear option. Not all countries have climates and weather suited to alternative energy and their environmental impact (visual and sometimes through the noise they can create) creates opponents to these methods. The next section discusses this topic in more detail.

Pollution by contraceptive hormones

When women use the contraceptive pill, the hormones in it (oestrogen or progesterone – Chapter 16) are excreted in urine and become present in sewage. The process of sewage treatment does not extract the hormones, so they end up in water systems such as rivers, lakes and the sea. Their presence in this water affects aquatic organisms as they enter food chains. For example, male frogs and fish can become 'feminised' (they can start producing eggs in their testes instead of sperm). This causes an imbalance between numbers of male and female animals (more females than males).

Drinking water, extracted from rivers where water from treated sewage has been recycled, can also contain the hormones. This has been shown to reduce the sperm count in men, causing a reduction in fertility.

It should be noted that the contraceptive pill is not the only source of female hormones in water systems: natural hormones are also present in urine from cattle, for example, and these can enter the water with run-off from farms.

Conservation

Key definition
A **sustainable resource** is one that is produced as rapidly as it is removed from the environment so that it does not run out.

Non-renewable resources such as fossil fuels need to be conserved because the stocks of them on the planet are finite: coal, oil, natural gas and minerals (including metallic ores) cannot be replaced once their sources have been totally depleted. Estimates of how long these stocks will last are unreliable but in some cases, e.g. lead and tin, they are less than 100 years.

By the time that fossil fuels run out, we will have to have alternative sources of energy. Even the uranium used in nuclear reactors is a finite resource and will, one day, run out.

The alternative sources of energy available to us are hydroelectric, nuclear, wind and wave power, wood and other plant products. The first two are well established; the others are either in the experimental stages, making only a small contribution, or are more expensive (at present) than fossil fuels (Figure 21.31). Plant products are **renewable resources** and include alcohol distilled from fermented sugar (from sugar-cane), which can replace or supplement petrol (Figure 21.32), sunflower oil, which can replace diesel fuel, and wood from fast-growing trees. In

Figure 21.31 Wind generators in the USA. On otherwise unproductive land or offshore, these generators make an increasing contribution to the electricity supply.

addition, plant and animal waste material can be decomposed anaerobically in fermenters to produce **biogas**, which consists largely of methane.

Chemicals for industry or drugs, currently derived from petroleum, will have to be made from plant products.

In theory, fuels produced from plant sources should have a minimal effect on the carbon dioxide concentration in the atmosphere and, therefore, on global warming. The carbon dioxide released when they are burned derives from the carbon dioxide they absorbed during their photosynthesis. They are '**carbon neutral**'. However, the harvesting of the crop and the processes of extraction and distillation all produce carbon dioxide. The net effect on atmospheric carbon dioxide is questionable.

Also, the clearing of forests to make space for fuel crops removes a valuable carbon sink and the burning that accompanies it produces a great deal of carbon dioxide. In addition, the use of land for growing crops for **biofuels** reduces the land available for growing food and increases the price of food.

Currently, the benefit of deriving fuel from plant material is open to question.

When **non-renewable resources** run out they will have to be replaced by recycling or by using man-made materials derived from plant products. Already some bacteria have been genetically engineered to produce substances that can be converted to plastics.

Some resources, such as forests and fish stocks can be maintained with careful management. This may involve replanting land with new seedlings as mature trees are felled and controlling the activities of fishermen operating where fish stocks are being depleted.

Figure 21.32 An alcohol-powered car in Brazil

Recycling

As minerals and other resources become scarcer, they also become more expensive. It then pays to use them more than once. The recycling of materials may also reduce the amount of energy used in manufacturing. In turn this helps to conserve fuels and reduce pollution.

For example, producing aluminium alloys from scrap uses only 5% of the energy that would be needed to make them from aluminium ores. In 2000, Europe recycled 64.3% of the aluminium in waste. Germany and Finland do really well, partly because they have a deposit scheme on cans: they recycle between 95 and 96% of their aluminium waste.

About 60% of the lead used in Britain is recycled. This seems quite good until you realise that it also means that 40% of this poisonous substance enters the environment.

Manufacturing glass bottles uses about three times more energy than if they were collected, sorted, cleaned and reused. Recycling the glass from bottles does not save energy but does reduce the demand for sand used in glass manufacture. In 2007, 57% of glass containers were recycled in Britain.

Polythene waste is now also recycled (Figure 21.33). The plastic is used to make items such as car seat covers, sports shoes, hi-fi headphones and even bridges (Figure 21.34).

Waste paper can be pulped and used again, mainly for making paper and cardboard. Newspapers are de-inked and used again for newsprint. One tonne of waste paper is equivalent to perhaps 17 trees. (Paper is made from wood-pulp.) So collecting waste paper may help to cut a country's import bill for timber and spare a few more hectares of natural habitat from the spread of commercial forestry.

Sewage treatment

Micro-organisms, mainly bacteria and protoctista, play an essential part in the treatment of sewage to make it harmless.

Sewage contains bacteria from the human intestine that can be harmful (Chapter 10). These bacteria must be destroyed in order to prevent the spread of intestinal diseases. Sewage also contains substances from household wastes (such as soap and detergent) and chemicals from factories. These too must be removed before the sewage effluent is released into the rivers. Rainwater from the streets is also combined with the sewage.

Figure 21.33 Recycling polythene. Polythene waste is recycled for industrial use.

Inland towns have to make their sewage harmless in a sewage treatment plant before discharging the effluent into rivers. A sewage works removes solid and liquid waste from the sewage, so that the water leaving the works is safe to drink.

In a large town, the main method of sewage treatment is by the activated sludge process (Figures 21.35 and 21.36).

The activated sludge process

1 **Screening.** The sewage entering the sewage works is first 'screened'. That is, it is made to flow through a metal grid, which removes the solids like rags, plastics, wood and so forth. The 'screenings' are raked off and disposed of – by incineration, for example.
2 **Grit.** The sewage next flows slowly through long channels. As it flows, grit and sand in it settle down to the bottom and are removed from time to time. The grit is washed and used for landfill.
3 **First settling tanks.** The liquid continues slowly through another series of tanks. Here about 40% of the organic matter settles out as crude sludge.

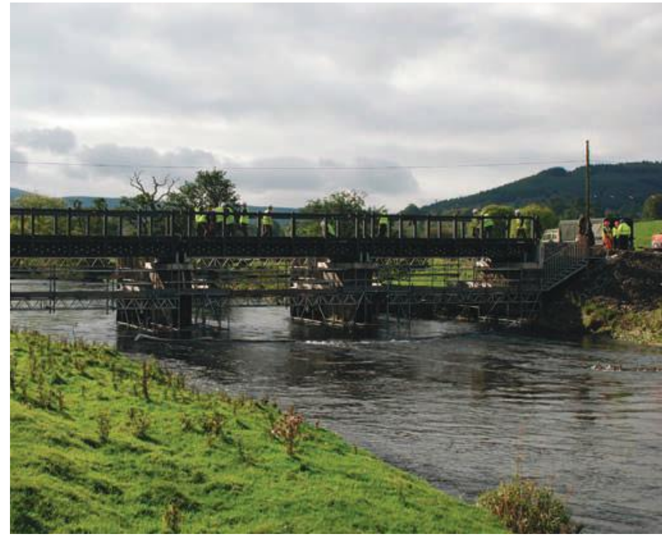


Figure 21.34 The world's longest bridge made from recycled plastic. It was constructed in Peeblesshire in Scotland.

The rest of the organic matter is in the form of tiny suspended particles, which pass, with the liquid, to the aeration tanks.

The semi-liquid sludge from the bottom of the tank is pumped to the sludge digestion plant.

4 **Aeration tanks.** Oxygen is added to the sewage liquid, either by stirring it or by bubbling compressed air through it. Aerobic bacteria and protoctista grow and reproduce rapidly in these conditions.

These micro-organisms clump the organic particles together. Enzymes from the bacteria digest the solids to soluble products, which are absorbed by the bacteria and used for energy and growth.

Dissolved substances in the sewage are used in the same way. Different bacteria turn urea into ammonia, ammonia into nitrates and nitrates into nitrogen gas. The bacteria derive energy from these chemical changes. The protoctista (Figure 21.37) eat the bacteria.

In this way, the suspended solids and dissolved substances in sewage are converted to nitrogen, carbon dioxide (from respiration) and the cytoplasm of the bacteria and protoctista, leaving fairly pure water.

5 **Second settling tanks.** The micro-organisms settle out, forming a fine sludge, which is returned to the aeration tanks to maintain the population of micro-organisms. This is the 'activated sludge' from which the process gets its name. The sewage

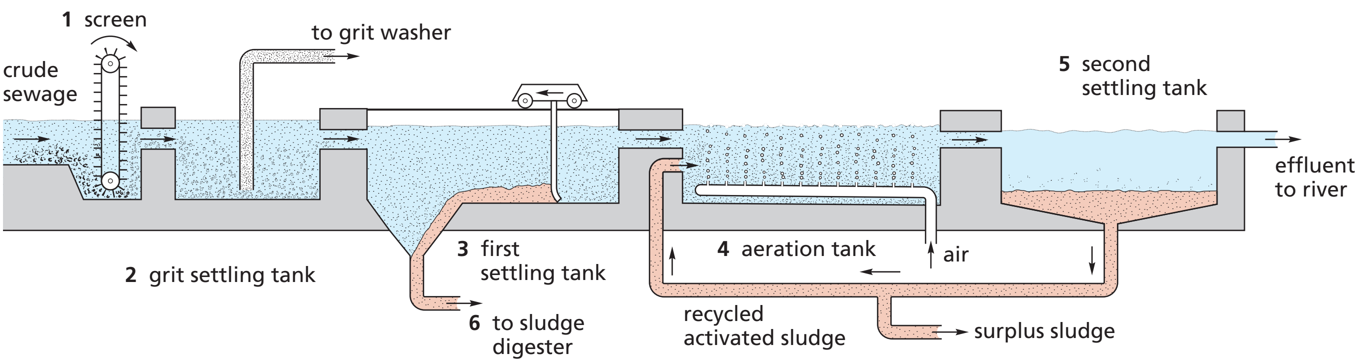


Figure 21.35 Sewage treatment – activated sludge process

stays in the aeration tanks for only 6–8 hours but the recycling of activated sludge allows the micro-organisms to act on it for 20–30 days.

6 When all the sludge has settled, the water is pure enough to discharge into a river and the sludge passes to a digester, which is used to produce methane (biogas).

Figure 21.36 Sewage treatment – activated sludge method. In the foreground are the rectangular aeration tanks.

Biogas production is not confined to sludge. Many organic wastes, e.g. those from sugar factories, can be fermented anaerobically to produce biogas. In developing countries, biogas generators use animal dung to produce methane for whole villages. On a small scale, biogas is a useful form of sustainable alternative energy.

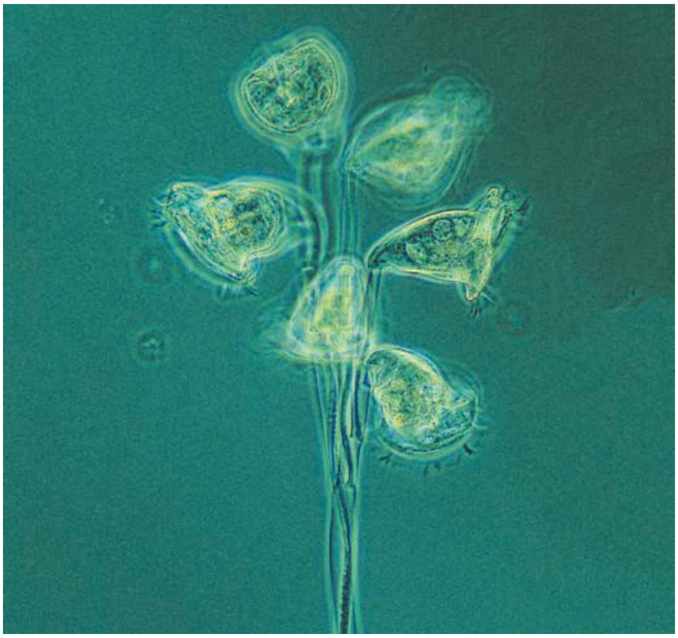


Figure 21.37 Protoctista in activated sludge (×150). These single-celled organisms ingest bacteria in the liquid sewage.

Endangering species and causing their extinction

Anything that reduces the population of a species endangers it (puts it at risk of extinction). Factors that endanger species include habitat destruction, the introduction of other species, hunting, international trade or pollution. Climate change can also put species at risk of extinction.

Species become extinct in the course of evolution. After all, the fossil remains of plants and animals represent organisms that became extinct hundreds of thousands of years ago. There have been periods of mass extinction, such as that which wiped out the dinosaurs during the Cretaceous era, 65 million years ago.

The 'background' extinction rate for, say, birds might be one species in 100–1000 years. Today, as a result of human activity, the rate of extinction has gone up by at least ten times and possibly as much as 1000 times. Some estimates suggest that the world is losing one species every day and within 20 years at least 25% of all forms of wildlife could become extinct. Reliable evidence for these figures is hard to obtain, however.

A classic example is the colonisation of the Pacific islands by the Polynesians. They hunted and ate the larger bird species, and introduced rats, which ate the eggs and young of ground-nesting species. Their goats and cattle destroyed plant species through grazing and trampling. Of about 1000 plant species, 85% has been lost since they were first discovered.

This may be an extreme example but the same sorts of changes are happening all over the world. For example, the World Wide Fund for Nature (WWF) estimated that only about 3200 tigers remained in the wild in 2011. This is less than 5% of their number in 1900 (Figure 21.38). They are hunted for their skins and their bones and some body parts are used in traditional Chinese medicines.

Figure 21.38 In 110 years the tiger population has fallen from 120 000 to 3200.

Some species of animal are not introduced deliberately into different ecosystems, but find their way in due to man's activities and then upset food chains. One example happened in the Great Lakes in Canada and the USA. The lakes were artificially joined together with shipping canals to provide transport links, but sea lampreys found their way into the lakes through the new waterways. The lampreys had no natural predators in the lakes and fed on trout by sticking to them with their circular mouths and boring into their flesh (Figure 21.39). The fisheries in the lakes harvested about 7 million kilograms of trout annually before the lampreys entered the water systems. Afterwards, the harvest dropped to about 136 000 kilograms, so the fisheries collapsed. The lampreys are now controlled to enable the trout population to recover.

Figure 21.39 Sea lamprey feeding on a trout

Climate change is also responsible for a reduction in the number of species. Some people argue that this is a natural, uncontrollable process, but the consensus by scientists is that processes like global warming are made worse by human activity.

Global warming is causing oceans to warm up. Even prolonged temperature increases of just one or two degrees can have a devastating effect. In 1994, coral colonies (see Figure 1.8) in the Indian Ocean were observed to expel food-producing algae they are closely associated with. As the coral rely on the algae, if they lose them they die. The coral reefs became bleached. When the area was surveyed again in 2005, four fish species appeared to be extinct and six other species had declined to the point of being endangered. Increases in CO_2 in the sea also affect coral reefs. The CO_2 dissolves in the water, making it more acidic. The acid dissolves the calcium carbonate deposited in the coral, making it collapse.

Species such as the Atlantic cod are becoming endangered and at possible risk of extinction, partly because of overfishing (see Chapter 19) but also because of climate change. Cod survive in cold water.

As seawater warms up, the cod migrate north. However, the populations of microscopic plankton that cod rely on further down the food chain are also sensitive to temperature change – cod may not have the food supplies they need to survive.

Scientists developed a computer model to study the effect of climate change on fish stocks over the next 50 years. It predicted a large-scale redistribution of species and the extinction of some species, with the disruption of ecosystems and reduction in biodiversity.

Conservation of species

Species can be conserved by passing laws that make killing or collecting them an offence, by international agreements on global bans or trading restrictions, and by conserving habitats (Figure 21.40).

Habitats can be conserved in a number of ways:

- using laws to protect the habitat
- using wardens to protect the habitat
- reducing or controlling public access to the habitat
- controlling factors such as water drainage and grazing, that may otherwise help to destroy the habitat.

In Britain, it is an offence to capture or kill almost all species of wild birds or to take eggs from their nests; wild flowers in their natural habitats may not be uprooted; newts, otters and bats are just three of the protected species of mammal.

Many organisations monitor species numbers, so that conservation measures can be taken if they decline significantly.

CITES (Convention on International Trade in Endangered Species) gives protection to about 1500 animals and thousands of plants by persuading governments to restrict or ban trade in endangered species or their products, e.g. snake skins or rhino horns. In 2013, nearly 180 countries were party to the Convention.

The WWF operates on a global scale and is represented in 25 countries. The WWF raises money for conservation projects in all parts of the world, but with particular emphasis on endangered species and habitats.

The **IWC** (International Whaling Commission) was set up to try and avoid the extinction of whales as a result of uncontrolled whaling, and has 88 members.

Figure 21.40 Trying to stop the trade in endangered species. A customs official checks an illegal cargo impounded at a customs post.

The IWC allocates quotas of whales that the member countries may catch but, having no powers to enforce its decisions, cannot prevent countries from exceeding their quotas.

In 1982, the IWC declared a moratorium (i.e. a complete ban) on all whaling, which was reaffirmed in 2000 and is still in place in 2014, despite opposition from Japan and Norway. Japan continues to catch whales 'for scientific purposes'.

Captive breeding and reintroductions

Provided a species has not become totally extinct, it may be possible to boost its numbers by **breeding in captivity** and releasing the animals back into the environment. In Britain, modest success has been achieved with otters (Figure 21.41). It is important (a) that the animals do not become dependent on humans for food and (b) that there are suitable habitats left for them to recolonise.

Sea eagles, red kites (Figure 21.42) and ospreys have been introduced from areas where they are plentiful to areas where they had died out.

Figure 21.41 The otter has been bred successfully in captivity and released.

Figure 21.42 Red kites from Spain and Sweden have been reintroduced to Britain.

Seed banks

These are a way of protecting plant species from extinction. They include seed from food crops and rare species. They act as gene banks (see the next section). The Millennium Seed Bank Partnership was set up by Kew Botanical Gardens in London. It is a global project involving 80 partner countries. The target of the partnership is to have in storage 25% of the world's plant species with bankable seeds by 2020. That involves about 75 000 plant species.

Conservation of habitats

If animals and plants are to be conserved it is vital that their habitats are conserved also.

Habitats are many and varied: from vast areas of tropical forest to the village pond, and including such diverse habitats as wetlands, peat bogs, coral reefs, mangrove swamps, lakes and rivers, to list but a few.

International initiatives

In the last 30 years it has been recognised that conservation of major habitats needed international agreements on strategies. In 1992, the Convention on Biological Diversity was opened for signature at the 'Earth Summit' Conference in Rio, and 168 countries signed it. The Convention aims to preserve biological diversity ('biodiversity').

Biodiversity encompasses the whole range of species in the world. The Convention will try to share the costs and benefits between developed and developing countries, promote '**sustainable development**' and support local initiatives.

'Sustainable development' implies that industry and agriculture should use natural resources sparingly and avoid damaging natural habitats and the organisms in them.

Key definition

Sustainable development is development providing for the needs of an increasing human population without harming the environment.

The Earth Summit meeting addressed problems of population, global warming, pollution, etc. as well as biodiversity.

There are several voluntary organisations that work for worldwide conservation, e.g. WWF, Friends of the Earth and Greenpeace.

Sustaining forest and fish stocks

There are three main ways of sustaining the numbers of key species. These are:

1 Education

Local communities need to be educated about the need for conservation. Once they understand its importance, the environment they live in is more likely to be cared for and the species in it protected.

In tree-felling operations in tropical rainforests, it has been found that the process of cutting down the trees actually damages twice as many next to them and dragging the trees out of the forest also creates more damage. Education of the men carrying out the operations in alternative ways of tree felling, reduction of wastage and in the selection of species of trees to be felled makes the process more sustainable and helps to conserve rarer species.

In the **tomato fish project** in Germany (see later in this section), the Research Institute involved has an active education programme to inform the public about its work in sustainable development. It has even published a book for children (*Nina and the tomato fish*) to educate them about the topic.

2 Legal quotas

In Europe the Common Fisheries Policy is used to set quotas for fishing, to manage fish stocks and help protect species that were becoming endangered through overfishing (see Chapter 19). Quotas were set for each species of fish taken commercially and also for the size of fish. This was to allow fish to reach breeding age and maintain or increase their populations.

The Rainforest Alliance has introduced a scheme called *Smartlogging*. This is a certification service, which demonstrates that a logging company is working legally and is a sustainable way to protect the environment. The timber can be tracked from where it is felled to its final export destination and its use in timber products. The customer can then be reassured that the timber in the product is from a reputable source and has not been removed illegally.

In some areas of China where bamboo is growing, there are legal quotas to prevent too much felling. Some animals such as giant panda rely on the bamboo for their food.

In Britain it is illegal to cut down trees without permission. The Forestry Commission issues licenses for tree felling. Included in the license are conditions that the felled area must be replanted and the trees maintained for a minimum of ten years.

3 Restocking

Where populations of a fish species are in decline, their numbers may be conserved by a restocking programme. This involves breeding fish in captivity, then releasing them into the wild. However, the reasons for the decline in numbers need to be identified first. For example, if pollution was the cause of the decline, the restocked fish will die as well: the issue of pollution needs to be addressed first. Great care is needed in managing fish farms because they can produce pollution if the waste water from the farms, containing uneaten food and fish excreta, is discharged into the environment.

Organisations such as the Woodland Trust help to conserve areas of woodland and provide funding for restocking where species of trees are in decline. This is important as some animal species rely on certain trees for food and shelter. Large areas of land planted with single species (an example of a monoculture) create little biodiversity. In Britain, the Forestry Commission has been steadily increasing the range of tree species it plants, growing them in mixed woodland, which provides habitats for a wider range of animals.

Sustainable development

This is a complex process, requiring the management of conflicting demands. As the world's population grows, so does the demand for the extraction of resources from the environment. However, this needs to be carried out in a controlled way to prevent environmental damage and strategies need to be put in place to ensure habitats and species diversity are not threatened.

Planning the removal of resources needs to be done at local, national and international levels. This is to make sure that everyone involved with the process is aware of the potential consequences of the process on the environment, and that appropriate strategies are put in place, and adhered to, to minimise any risk.

Tomato fish project

The ASTAF-PRO project – Aquaponic System for (nearly) Emission-Free Tomato and Fish Production – in Germany is run by the Leibniz Institute of Freshwater Ecology and Inland Fisheries. The scientists have developed a way of simultaneously producing fish and tomatoes in a closed greenhouse environment. Both organisms thrive at a temperature of 27 °C. The system is almost emission-free (so atmospheric CO_2 levels are not affected), recycles all the water in the process and does not put any waste into the environment (Figure 21.43). All the energy needed to heat the greenhouses is generated by solar panels. These factors make it a sustainable and climate-friendly method of food production. The scientists recognised that fish and plants have very similar environmental needs for their growth. Nile Tilapia (*Oreochromis niloticus*) is chosen as the fish species, because they survive well in artificial conditions, growing and maturing quickly. Since they are omnivorous as adults, no fish meal diet is needed, and they can be fed with pellets of processed food extracted from plants. Water from the fish tanks is cleaned and the nutrients remaining in it are used as a fertiliser for tomato plants, grown in the same greenhouse (Figure 21.44).

The plants are grown on mineral wool, through which the nutrient-rich water flows. This avoids soil, which can contain pathogens. This method of growing plants, called **hydroponics**, also means that no peat is needed for soil. The removal of peat for use in horticulture is threatening heathland and the organisms living on it.

As the tomato plants transpire, the water vapour is condensed and recycled into the fish tanks. The tomatoes are harvested and sold under the name 'fish tomatoes'. The scientists call the project 'The Tomatofish'. The next goal is to implement the system into global food production systems.

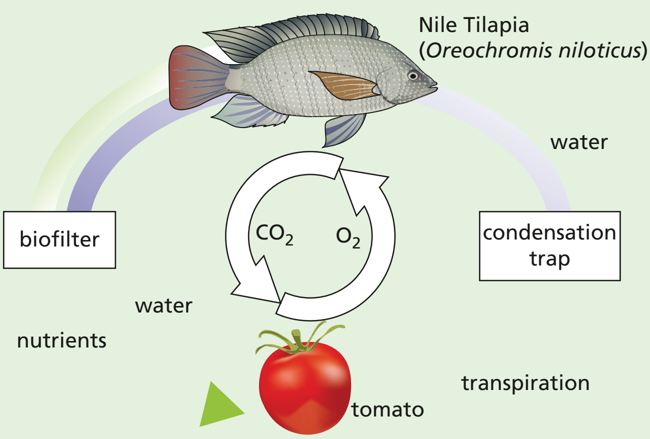


Figure 21.43 The tomato-fish project

Figure 21.44 Tomatoes and fish being grown in the same environment

Conservation programmes

If the population of a species drops, the range of variation within the species drops, making it less able to adapt to environmental change. The species could, therefore, be threatened with extinction. When animal populations fall, there is less chance of individuals finding each other to mate.

In 'Selection', Chapter 18, it was explained that crossing a wild grass with a strain of wheat produced an improved variety. This is only one example of many successful attempts to improve yield, drought resistance and disease resistance in food plants. Some 25 000 plant species are threatened with extinction at the moment. This could result in a devastating loss of hereditary material and a reduction of about 10% in the genes available for crop improvement. 'Gene banks' have been set up to preserve a wide range of plants, but these banks are vulnerable to accidents, disease and human error. The only secure way of preserving the full range of genes is to keep the plants growing in their natural environments.

Conservation programmes are set up for a number of reasons:

Reducing extinction

Conservation programmes strive to prevent extinction. Once a species becomes extinct its genes are lost forever, so we are also likely to deprive the world of genetic resources. Apart from the fact that we have no right to wipe out species forever, the chances are that we will deprive ourselves not only of the beauty and diversity of species but also of potential sources of valuable products such as drugs. Many of our present-day drugs are derived from plants (e.g. quinine and aspirin) and there may be many more sources as yet undiscovered.

Protecting vulnerable environments

Conservation programmes are often set up to protect threatened habitats so that rare species living there are not endangered. Some species of plant require very special conditions to grow successfully, for instance wet, acidic conditions associated with heathland (see Figure 21.46). Some animal species have very limited diets or other needs: the large heath butterfly only feeds on one type of plant called cottongrass. If that plant was allowed to become extinct, perhaps through drainage of the peat bog land on which the cottongrass lives, the butterflies would die out as well.

There are a number of organisations involved with habitat conservation in Britain. English Nature, the Countryside Council for Wales and Scottish Natural Heritage were formed from the Nature Conservancy Council (NCC). They are regulatory bodies committed to establish, manage and maintain nature reserves, protect threatened habitats and conduct research into matters relevant to conservation.

The NCC established 195 nature reserves (Figure 21.45) but, in addition, had responsibility for notifying planning authorities of **Areas of Special Scientific Interest** (**ASSIs**), also known as Sites of Special Scientific Interest (SSSIs). These are privately owned lands that include important habitats or rare species (Figure 21.46). English Nature and other conservation bodies establish management agreements with the owners so that the sites are not damaged by felling trees, ploughing land or draining fens (Figure 21.47).

Figure 21.45 An English Nature National Nature Reserve at Bridgewater Bay in Somerset. The mudflats and saltmarsh attract large numbers of wintering wildfowl.

There are now about 5000 ASSIs, and the Countryside and Rights of Way Act of 2000 has strengthened the rules governing the maintenance of ASSIs.

There are several other, non-governmental organisations that have set up reserves and which help to conserve wildlife and habitats. There are 47 Wildlife Trusts in the UK, managing thousands of sites. The Royal Society for the Protection of Birds (RSPB) has 200 sites, the Woodland Trust looks after over 1100 woods and there are about 160 other reserves managed by other organisations.

Figure 21.46 Area of Special Scientific Interest. This heathland in Surrey is protected by a management agreement with the landowner.

Figure 21.47 The Royal Society for the Protection of Birds (RSPB) maintains this wet grassland by Loch Leven, Scotland, for nesting redshanks, snipe, lapwings and ducks.

The National Parks Commission has set up 15 National Parks covering more than 9% of England and Wales, e.g. Dartmoor, Snowdonia and the Lake District. Although the land is privately owned, the Park Authorities are responsible for protecting the landscape and wildlife, and for planning public recreation such as walking, climbing or gliding.

The European Commission's **Habitats Directive** of 1994 requires member states to designate **Special Areas of Conservation** (**SACs**) to protect some of the most seriously threatened habitats and species throughout Europe. The UK has submitted a list of 340 sites, though many of these are already protected areas, such as ASSIs.

Desirable though ASSIs, National Parks and SACs are, they represent only relatively small, isolated areas of land. Birds can move freely from one area to another, but plants and small animals are confined to an isolated habitat so are subject to risks that they cannot escape. If more farmland were managed in a way 'friendly' to wildlife, these risks could be reduced.

The Farming and Wildlife Advisory Group can advise farmers how to manage their land in ways that encourage wildlife. This includes, for example, leaving strips of uncultivated land around the margins of fields or planting new hedgerows. Even strips of wild grasses and flowers between fields significantly increase the population of beneficial insects.

Certain areas of farmland have been designated as Environmental Sensitive Areas (ESAs), and farmers are paid a subsidy for managing their land in ways that conserve the environment.

Maintaining ecosystem functions

There is a danger of destabilising food chains if a single species in that food chain is removed. For example, in lakes containing pike as the top predators, overfishing can result in smaller species of carnivorous fish, such as minnows, increasing in numbers. They eat zooplankton. If the minnows eat the majority of the zooplankton population, it leaves no herbivores to control algal growth, which can cause an algal bloom when there are sufficient nutrients to support this growth. To prevent such an event happening, the ecosystem needs to be maintained, by controlling the numbers of top predators removed, or by regular restocking.

Ecosystems can also become unbalanced if the nutrients they rely on are affected in some way. Guano is the accumulated droppings of seabirds and bats. It is extremely rich in nitrogen compounds and phosphates, so it makes a valuable fertiliser. In the early 1900s Peru and South Africa both developed guano industries based on sustained-yield production from marine birds. However, overfishing around their coastlines reduced fish stocks, removing the food the seabirds relied on. As the seabird populations diminished, they deposited less guano and the guano industries failed.

The term ecosystem services can be defined as the benefits people obtain from ecosystems, whether they are natural or managed. Humans are affecting ecosystems on a large scale because of the growth in the population (Chapter 19) and changing patterns of consumption. Scientists estimate that around 40% of the Earth's land surface area is taken over by some form of farmed land. Crops are grown for food (directly, or indirectly through their use in feeding animals), extraction of drugs (both legal and illegal) and the manufacture of fuel (see details about biofuels below). Crop growth has major impacts in ecosystems, causing the extinction of many species and reducing the gene pool.

In theory, biofuels produced from plant sources should have a minimal effect on the carbon dioxide concentration in the atmosphere and, therefore, on global warming. The carbon dioxide released when they are burned derives from the carbon dioxide they absorbed during their photosynthesis. They are 'carbon neutral'. However, the harvesting of the crop and the processes of extraction and distillation all produce carbon dioxide. The net effect on atmospheric carbon dioxide is questionable. More details of biofuels are given in Chapter 20.

Also, the clearing of forests to make space for fuel crops removes a valuable carbon sink and the burning that accompanies it produces a great deal of carbon dioxide. In addition, the use of land for growing crops for biofuels reduces the land available for growing food and increases the price of food. Currently, the benefit of deriving fuel from plant material is open to question.

With all these demands on resources from ecosystems, it is a very complicated process to manage them effectively and this makes conservation programmes invaluable to protect species and their habitats.

Questions

Core

1 The graph in Figure 21.8 shows the change in the numbers of mites and springtails in the soil after treating it with an insecticide. Mites eat springtails. Suggest an explanation for the changes in numbers over the 16-month period.
2 What are the possible dangers of dumping and burying poisonous chemicals on the land?
3 Before most water leaves the waterworks, it is exposed for some time to the poisonous gas, chlorine. What do you think is the point of this?
4 If the concentration of mercury in Minamata Bay was very low, why did it cause such serious illness in humans?
5 Explain why some renewable energy sources depend on photosynthesis.
6 In what ways does the recycling of materials help to save energy and conserve the environment?
7 Explain why some of the alternative and renewable energy sources are less likely to cause pollution than coal and oil.
8 What kinds of human activity can lead to the extinction of a species?
9 How do the roles of CITES and WWF differ? In what respects might their activities overlap?
10 How might the loss of a species affect:
  a our health (indirectly)
  b the prospect of developing new varieties of crop plants resistant to drought?
11 What part do micro-organisms (bacteria and protoctista) play in sewage treatment?
12 What do you understand by:
  a biodiversity
  b sustainable development?
13 What is the difference between an ASSI and a nature reserve?

Extended

14 a What pressures lead to destruction of tropical forest?
  b Give three important reasons for trying to preserve tropical forests.
15 In what ways might trees protect the soil on a hillside from being washed away by the rain?
16 If a farmer ploughs a steeply sloping field, in what direction should the furrows run to help cut down soil erosion?
17 What is the possible connection between:
  a cutting down trees on hillsides and flooding in the valleys, and
  b clear-felling (logging) in tropical forests and local climate change?
18 To what extent do tall chimneys on factories reduce atmospheric pollution?
19 What are thought to be the main causes of 'acid rain'?
20 Why are carbon dioxide and methane called 'greenhouse gases'?

Checklist

Food supply

- Modern technology has resulted in increased food production.
- Agricultural machinery can be used on larger areas of land to improve efficiency.
- Chemical fertilisers improve yields.
- Insecticides improve quality and yield.
- Herbicides reduce competition with weeds.
- Selective breeding improves production by crop plants and livestock.
- Monocultures can have negative impacts on the environment.
- Intensive farming has resulted in habitat deterioration and reduction of wildlife.

- Problems with world food supplies contribute to difficulties providing enough food for an increasing human global population.
- Food production in developed countries has increased faster than the population growth.
- Food production in developing countries has not kept pace with population growth.
- Problems that contribute to famine include unequal distribution of food, drought, flooding and an increasing population.

Habitat destruction

- There are a number of reasons for habitat destruction, including:
  – increased area needed for food-crop growth, livestock production and housing
  – the extraction of natural resources
  – marine pollution.
- Through altering food webs and food chains, humans can negatively impact on habitats.
- Deforestation is an example of habitat destruction: it can lead to extinction, soil erosion, flooding and carbon dioxide build-up in the atmosphere.
- The conversion of tropical forest to agricultural land usually results in failure because forest soils are poor in nutrients.

- Deforestation has many undesirable effects on the environment.

Pollution

- We pollute our lakes, rivers and the sea with industrial waste, sewage, crude oil, rubbish, factory wastes and nuclear fall-out.
- Use of fertilisers can result in water pollution.
- Pesticides kill insects, weeds and fungi that could destroy our crops.
- Pesticides help to increase agricultural production but they kill other organisms as well as pests.

- A pesticide or pollutant that starts off at a low, safe level can become dangerously concentrated as it passes along a food chain.
- Eutrophication of lakes and rivers results from the excessive growth of algae followed by an oxygen shortage when the algae die and decay.
- We pollute the air with smoke, sulfur dioxide and nitrogen oxides from factories, and carbon monoxide and nitrogen oxides from motor vehicles.
- The acid rain resulting from air pollution leads to poisoning of lakes and possibly destruction of trees.
- The extra carbon dioxide from fossil fuels might lead to global warming.

- The process of eutrophication of water involves:
  - increased availability of nitrate and other ions
  - increased growth of producers
  - increased decomposition after death of the producers
  - increased aerobic respiration by bacteria, resulting in a reduction in dissolved oxygen
  - the death of organisms requiring dissolved oxygen in water.
- Non-biodegradable plastics can have detrimental effects on aquatic and terrestrial ecosystems.
- Sulfur dioxide, produced by burning fossil fuels, causes acid rain. This kills plants, as well as animals in water systems.
- Measures that might be taken to reduce sulfur dioxide pollution and reduce the impact of acid rain include a reduction in use of fossil fuels.
- Methane and carbon dioxide are building up in the atmosphere, resulting in the enhanced greenhouse effect and climate change.
- Female contraceptive hormones are entering water courses and can cause reduced sperm count in men and feminisation of aquatic organisms.

Conservation

- A sustainable resource is one that can be removed from the environment without it running out.
- Raw materials, such as metal ores, will one day run out.
- We need to conserve non-renewable resources such as fossil fuels.
- When supplies of fossil fuels run out or become too expensive, we will need to develop alternative sources of energy.
- Recycling metals, paper, glass and plastic helps to conserve these materials and save energy.
- Some resources such as forests and fish stocks can be maintained.
- Sewage can be treated to make the water that it contains safe to return to the environment or for human use.
- Some organisms are becoming endangered or extinct due to factors such as climate change, habitat destruction, hunting, pollution and introduced species.
- Endangered species can be conserved by strategies that include monitoring and protecting species and habitats, education, captive breeding programmes and seed banks.

- Sustainable development is development providing for the needs of an increasing human population without harming the environment.
- Forest and fish stocks can be sustained using strategies such as education and legal quotas.
- Sustainable development requires the management of conflicting demands, as well as planning and co-operation at local, national and international levels.
- Although extinction is a natural phenomenon, human activities are causing a great increase in the rates of extinction.
- Conservation of species requires international agreements and regulations.
- These regulations may prohibit killing or collecting species and prevent trade in them or their products.
- Loss of a plant species deprives us of (a) a possible source of genes and (b) a possible source of chemicals for drugs.
- Conserving a species by captive breeding is of little use unless its habitat is also conserved.
- The Earth Summit Conference tried to achieve international agreement on measures to conserve wildlife and habitats, and reduce pollution.
- National Parks, nature reserves, ASSIs and SACs all try to preserve habitats but they cover only a small proportion of the country and exist as isolated communities.
- Incentives exist for farming in a way that is friendly to wildlife.

Examination questions

Do not write on these pages. Where necessary copy drawings, tables or sentences.

Characteristics and classification of living organisms

1 Four of the classes of vertebrates and five possible descriptions of these classes are shown below. Draw a straight line to match each class of vertebrate to its description. [4]

class of vertebrate	description
bird	body with naked skin, two pairs of limbs
fish	body with hair, two pairs of limbs
mammal	body with feathers, one pair of wings
reptile	body with scales, with fins
	body with scaly skin, two pairs of limbs or no limbs

[Total: 4]

(Cambridge IGCSE Biology 0610 Paper 2 Q1 November 2006)

2 **a** Three characteristics of living organisms and four possible descriptions are shown below. Draw a straight line to match each characteristic to its description. [3]

characteristic	description
respiration	pumping air in and out of the lungs
nutrition	producing new individuals of the same species
reproduction	obtaining organic chemicals for the repair of tissues
	the release of energy from sugars

b State **two** other characteristics of living organisms. [2]

[Total: 5]

(Cambridge IGCSE Biology 0610 Paper 2 Q1 June 2006)

3 Vertebrate animals are grouped into a number of classes.
Complete the sentences by naming each of the vertebrate classes that are described.

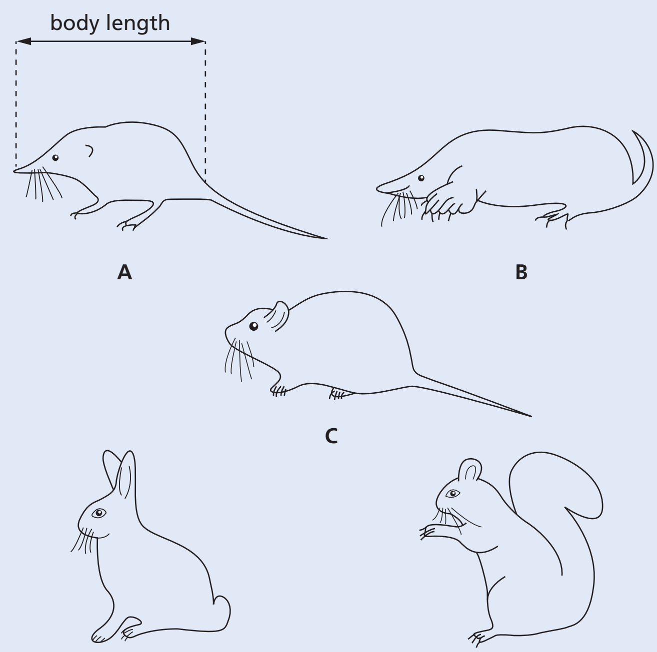
a A vertebrate with scaly skin and no legs could be either a ____________ or a ____________. [2]

b A vertebrate with lungs and hair is a ____________ but if it has feathers instead of hair it is a ____________. [2]

[Total: 4]

(Cambridge IGCSE Biology 0610 Paper 21 Q1 November 2012)

4 The diagram below shows five mammals.



(mammals not drawn to scale)

a Use the key to identify each of these mammals. Write the letter for each mammal in the table. [4]

1 tail more than half that of body length .... go to 2
  tail less than half that of body length .... go to 4

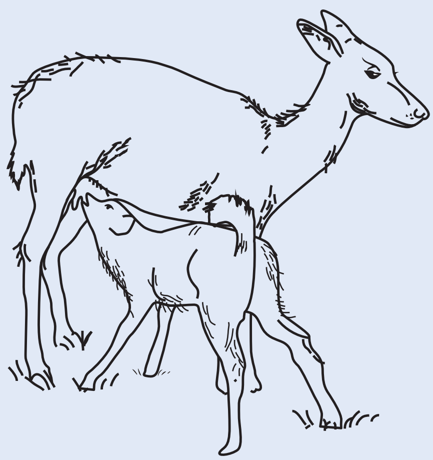
2 ears at top of head, with thick tail ...... *Sciurus caroliniensis*
  ears at side of head, with thin tail .... go to 3

3 nose pointed, nose length longer than its depth ...... *Sorex araneus*
  nose blunt, nose length shorter than its depth .... *Clethrionomys glareolus*

4 front legs as wide or wider than long .... *Talpa europaea*
  front legs longer than wide .... *Oryctolagus cuniculus*

Name of animal	Letter
Clethrionomys glareolus	
Oryctolagus cuniculus	
Sciurus caroliniensis	
Sorex araneus	
Talpa europaea	

b The diagram below shows a young deer feeding from its mother.



State **two** features, visible in the diagram, that distinguish mammals from other vertebrates. [2]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 3 Q1 November 2006)

5 The table below shows some of the external features of the five classes of vertebrates. Complete the table by placing a tick (✓) to indicate if each class has the feature. [5]

class of vertebrate	external ear flap	feathers or fur	scaly skin	two pairs of limbs
amphibians				
birds				
fish				
mammals				
reptiles				

[Total: 5]

(Cambridge IGCSE Biology 0610 Paper 21 Q2 June 2010)

6 Vertebrates can be classified by their external features. Complete the paragraph by using the name of a vertebrate class in each space.

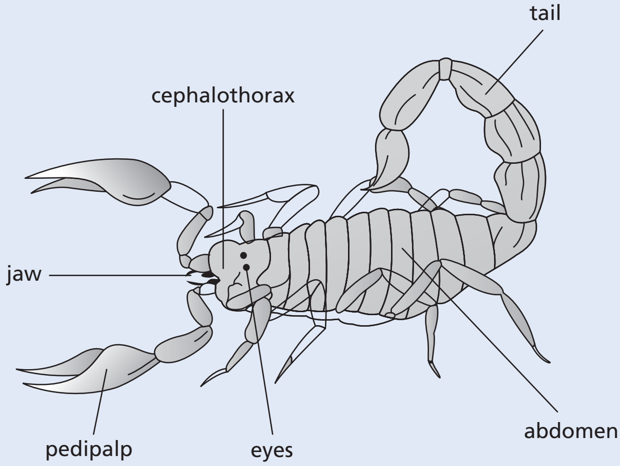
Some vertebrates have scales all over their skin. If they also have nostrils that allow air into their lungs and two pairs of legs they are ____________.

Some vertebrates have wings. If their body is also covered in feathers they are ____________, but if their body has fur they are ____________.
Vertebrates that do not have feathers, fur or scales on the outside of their body are ____________. [4]

[Total: 4]

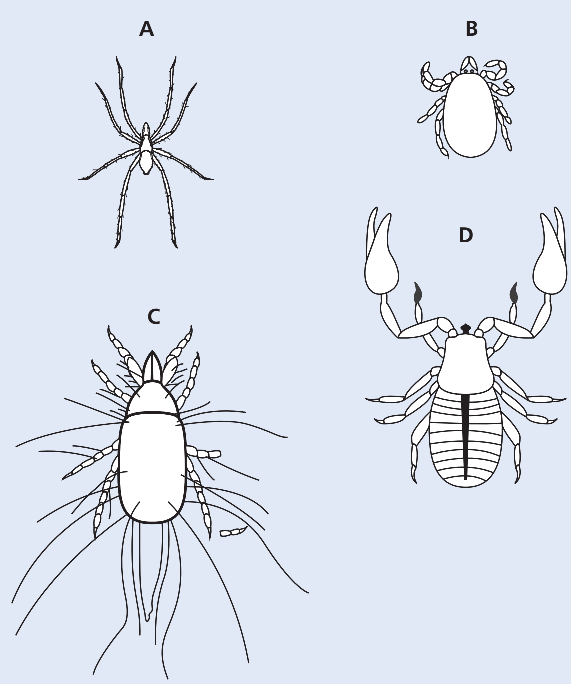
(Cambridge IGCSE Biology 0610 Paper 2 Q1 November 2009)

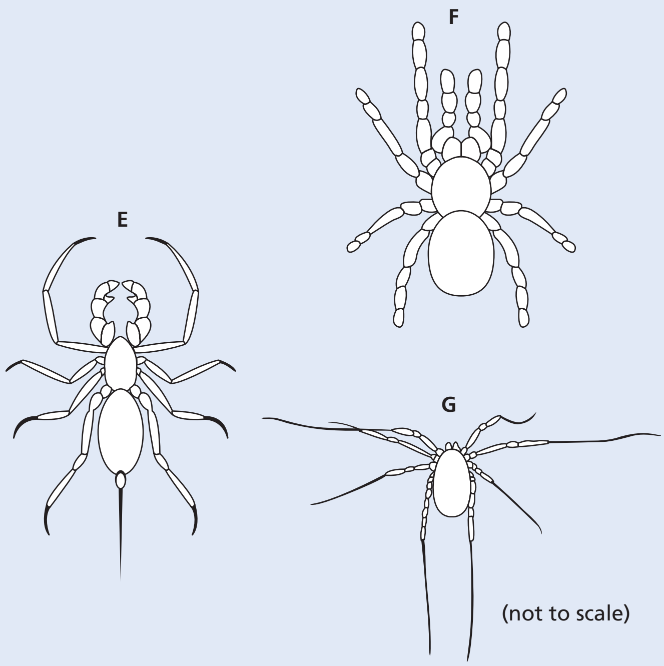
7 Arachnids, crustaceans, insects and myriapods are all classified as arthropods.
Scorpions, such as *Heterometrus swammerdami* shown in the diagram below, are arachnids.



a State **three** features, shown by *H. swammerdami* and **visible** in the diagram above that arachnids share with other arthropods. [3]

b The diagram below shows seven species of arachnid.





(not to scale)

Use the key to identify each species. Write the letter of each species (A to G) in the correct box beside the key. One has been done for you. [4]

Key

1	a)	Abdomen with a tail	*Abaliella dicranotarsalis*	E
	b)	Abdomen without a tail	go to 2	
2	a)	Legs much longer than abdomen and cephalothorax	go to 3	
	b)	Legs not much longer than abdomen and cephalothorax	go to 4	
3	a)	Hairs on legs	*Tegenaria domestica*	
	b)	No hairs on legs	*Odielus spinosus*	
4	a)	Cephalothorax or abdomen segmented	*Chelifer tuberculatus*	
	b)	Cephalothorax or abdomen not segmented	go to 5	
5	a)	Abdomen and cephalothorax about the same size	*Poecilotheria regalis*	
	b)	Abdomen larger than cephalothorax	go to 6	
6	a)	Body covered in long hairs	*Tyroglyphus longior*	
	b)	Body not covered in hairs	*Ixodes hexagonus*	

[Total: 7]

(Cambridge IGCSE Biology 0610 Paper 31 Q1 November 2012)

8 Non-living things, such as a car, often show characteristics similar to those of living organisms.

a State which characteristic of a living organism matches each of the descriptions linked to a car.

(i) burning fuel in the engine to release energy [1]

(ii) headlights that switch on automatically in the dark [1]

(iii) filling the car's tank with fuel [1]

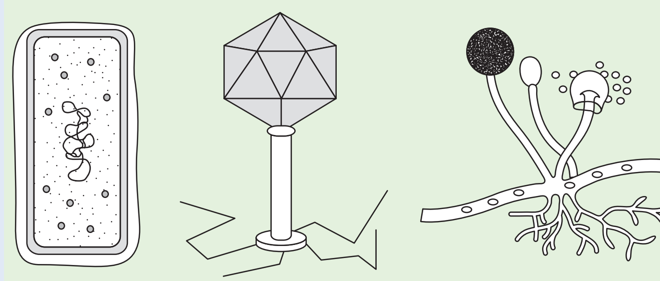
(iv) release of waste gases [1]

b Identify **one** characteristic of living things that is **not** carried out by a car. [1]

[Total: 5]

(Cambridge IGCSE Biology 0610 Paper 21 Q1 June 2012)

9 The diagram below shows a bacterium, a virus and a fungus.



(not to scale)

a Complete the table to compare the three organisms shown in the diagram above by using a tick (✓) to indicate if the organism shows the feature, or a cross (✗) if it does not. The first row has been completed for you. [3]

feature	bacterium	virus	fungus
produces spores	✗	✗	✓
hyphae			
capsule			
nucleus			

b Explain how the fungus shown in the diagram above is adapted to obtain its food. [3]

c Explain how the fungus spreads to new sources of food. [2]

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 31 Q1 November 2009)

Organisation and maintenance of the organism

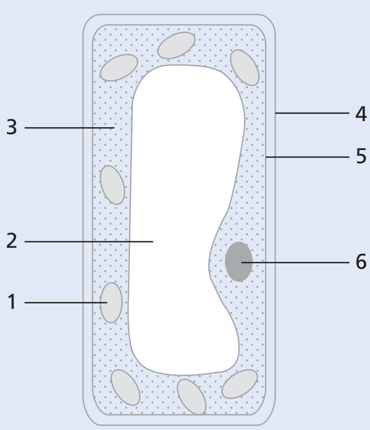
1 Five types of animal and plant cells and five possible functions of such cells are shown below. Draw one straight line from each type of cell to a function of that cell. [5]

type of cell	function of cell
red blood cell	absorption of mineral ions
root hair cell	transport of oxygen
white blood cell	movement of mucus
xylem	protection against pathogens
ciliated cell	structural support

[Total: 5]

(Cambridge IGCSE Biology 0610 Paper 2 Q5 June 2009)

2 The diagram shows a cell from the palisade layer of a leaf.



a In the table below tick (✓) the numbers that label the **three** features of the palisade cell which are also found in animal cells. [3]

label number	present in both animal and plant cells
1	
2	
3	
4	
5	
6	

b State and describe the function of **two** features of the palisade cell that are only found in plant cells. [4]

c The photograph below shows some red blood cells, which are animal cells.

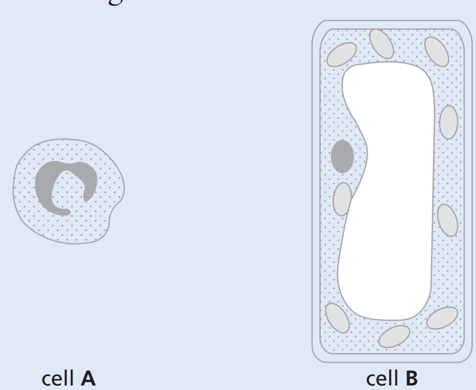
(i) Which feature normally present in an animal cell is absent from a red blood cell? [1]

(ii) State the function of a red blood cell **and** describe **one** way in which the red blood cell is adapted to carry out its function. [2]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q8 November 2012)

3 The diagram below shows two cells.



a (i) State where, in a human, a cell of type **A** would normally be found. [1]

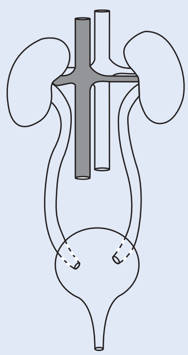
(ii) State where, in a plant, a cell of type **B** would be found. [1]

b Use only words from the list to complete the statements about cell **B**. [5]

air cellulose chloroplasts membrane mitochondria nucleus starch vacuole wall cell sap

Cell **B** has a thick layer called the cell ____________. This is made of ____________.
The cytoplasm of cell **B** contains many ____________ that are used in the process of photosynthesis. The large permanent ____________ is full of ____________ and this helps to maintain the shape of the cell.

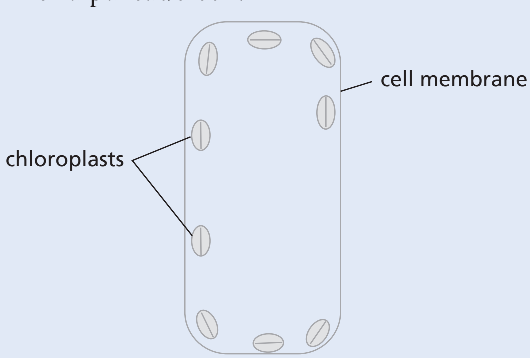
c The diagram below shows structures that produce urine and excrete it from the body of a mammal.



(i) On the diagram, label and name **one** organ. [1]
(ii) Use examples from the diagram to explain the difference between the terms *organ* and *organ system*. [3]

[Total: 11]
(Cambridge IGCSE Biology 0610 Paper 21 Q1 June 2010)

4 a The diagram shows a partly completed diagram of a palisade cell.



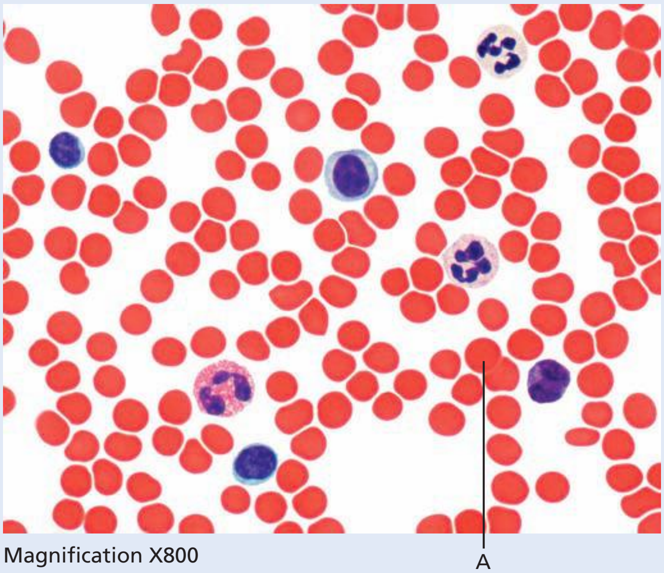
Complete the diagram to show the other major components of this cell.
Label all the components that you have added to the diagram. [4]

b State precisely where palisade cells are found in a plant. [2]

[Total: 6]
(Cambridge IGCSE Biology 0610 Paper 2 Q2 November 2009)

You may find it helpful to study Chapter 9 before attempting this question.

5 The photomicrograph below is of a human blood smear.



Magnification X800

a (i) On the photomicrograph, draw label lines and name **three** different types of blood cell. [3]
(ii) Name **two** parts of the blood that can pass through the capillary walls. [2]

b (i) Measure the diameter of the blood cell labelled **A**. [1]
(ii) The photomicrograph has been enlarged by × 800, calculate the actual size of cell **A**.
Show your working. [2]
(iii) State the function of cell **A**. [1]

[Total: 9]
(Cambridge IGCSE Biology 0610 Paper 6 Q3 June 2009)

Movement in and out of cells

1 Thin slices of dandelion stem were cut and placed into different salt solutions and left for 30 minutes.
Figure 1 shows how these slices were cut. Figure 2 shows the appearance of these pieces of dandelion stem after 30 minutes in the different salt solutions.

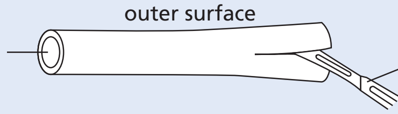


Figure 1

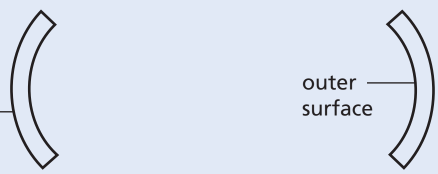


Figure 2

a (i) Describe the appearance of the pieces of dandelion stem in Figure 2. [2]

(ii) Explain what causes the two pieces of dandelion stem to change in the way you have described in **a(i)**. [4]

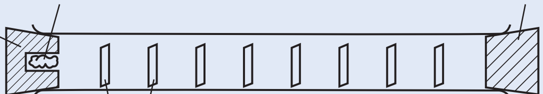
b Suggest how you could plan an investigation to find the concentration of salt solution which would produce no change from that shown in the original dandelion stem before being cut in Figure 1. [4]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 06 Q1 November 2009)

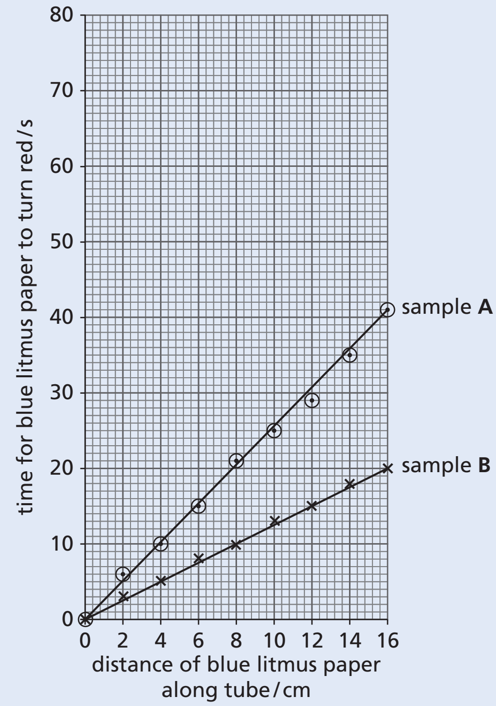
2 a Define *diffusion*. [2]

b The diagram below shows an apparatus that was used to investigate the effect of concentration of a chemical on the rate of diffusion.



As ethanoic acid diffused along the tube, the pieces of blue litmus paper turned red.

Two different samples of ethanoic acid, **A** and **B**, were used in this apparatus. The two samples had different concentrations. The results are shown in the graph.



The table shows the results for a third sample, **C**, of ethanoic acid.

distance of blue litmus paper along tube/cm	time for blue litmus paper to turn red/s
2	9
4	18
6	28
8	35
10	45
12	55
14	63
16	72

(i) Complete the graph above by plotting the results shown in the table above. [3]

(ii) State which sample of ethanoic acid, **A**, **B** or **C**, took the longest time to travel 8 cm along the tube. [1]

(iii) State and explain which sample of ethanoic acid was the most concentrated. [2]

c Substances can enter and leave cells by either diffusion or by osmosis.

State **two** ways in which osmosis differs from diffusion. [2]

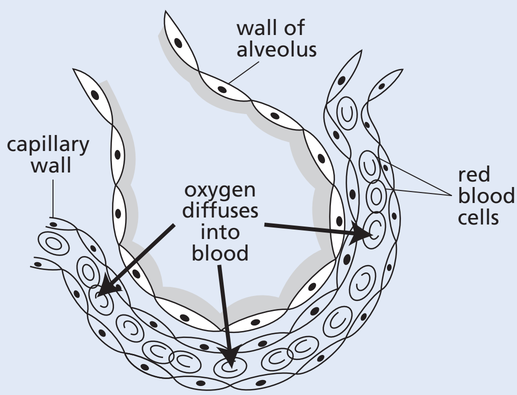
[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q3 June 2012)

3 a (i) Define *osmosis*. [3]
(ii) Osmosis is considered by many scientists to be a form of diffusion. Suggest **two** ways in which diffusion is different from osmosis. [2]
b (i) Explain how root hair cells use osmosis to take up water. [2]
(ii) The land on which a cereal crop is growing is flooded by sea water. Suggest the effect sea water could have on the cereal plants. [4]

[Total: 11]
(Cambridge IGCSE Biology 0610 Paper 2 Q9 November 2009)

4 The diagram shows an alveolus in which gaseous exchange takes place.



a (i) Define the term *diffusion*. [2]
(ii) State what causes oxygen to diffuse into the blood from the alveoli. [1]
(iii) List **three** features of gaseous exchange surfaces in animals, such as humans. [3]
b (i) At high altitudes there is less oxygen in the air than at sea level. Suggest how this might affect the uptake of oxygen in the alveoli. [2]
(ii) In the past some athletes have cheated by injecting themselves with extra red blood cells before a major competition. Predict how this increase in red blood cells might affect their performance. [2]

[Total: 10]
(Cambridge IGCSE Biology 0610 Paper 21 Q9 November 2006)

Biological molecules

1 The sweet potato, *Ipomoea batatus*, is a different species to the Irish potato, *Solanum tuberosum*.

sweet potato

Irish potato

a (i) Describe **one** similarity, visible in the photo, between the two species of potato. [1]
(ii) Complete the table to show two differences, visible in the photo, between the two species of potato. [2]

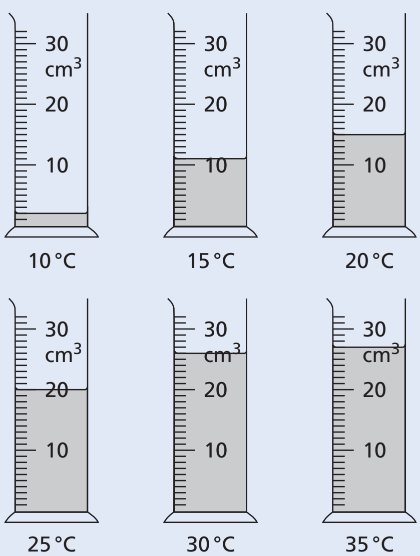
	sweet potato	Irish potato
difference 1		
difference 2		

b Potato crops are grown for their carbohydrate content.
Describe how you could safely test the two species of potato to compare their carbohydrate content.
test for starch
test for reducing sugar [8]

[Total: 11]
(Cambridge IGCSE Biology 0610 Paper 61 Q2 June 2010)

Enzymes

1 Enzymes are used commercially to extract fruit juices. The use of enzymes increases the volume of juice produced.
An investigation was carried out to determine the volume of apple juice produced at different temperatures.
Mixtures of apple pulp and enzyme were left for 15 minutes at different temperatures.
After 15 minutes, the mixtures were filtered and the juice collected.
The diagram shows the volume of juice collected from each mixture.



a (i) Record the volume of juice in each measuring cylinder in the table. [3]

temperature/°C	volume of juice collected/cm³
10	
15	
20	
25	
30	
35	

(ii) Present the data in a suitable graphical form. [5]
(iii) Describe the results. [2]

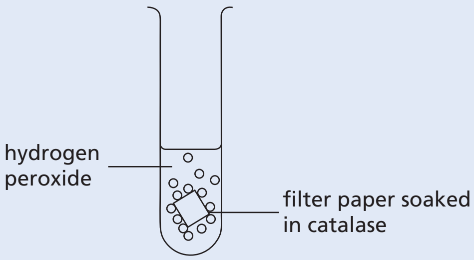
b Describe an investigation to show the effect of pH on the activity of the enzyme that is used to extract apple juice. [6]

[Total: 16]
(Cambridge IGCSE Biology 0610 Paper 61 Q1 November 2010)

2 Catalase is an enzyme that breaks down hydrogen peroxide into water and oxygen.

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

By using small pieces of filter paper soaked in a solution of catalase, it is possible to measure the enzyme activity.
The pieces are placed in a solution of diluted hydrogen peroxide in a test-tube.
The filter paper rises to the surface as oxygen bubbles are produced.
The time taken for these pieces of filter paper to rise to the surface indicates the activity of catalase.



An experiment was carried out to find the effect of pH on the activity of catalase.
Five test-tubes were set up as shown in the diagram, each with a different pH.
The same volume and concentration of hydrogen peroxide was used in each test-tube.
The table shows the results obtained for the experiment as described.

pH	time taken for filter paper to rise/s
3.0	62
4.0	54
5.0	35
6.0	25
7.0	20
8.0	50

a (i) Plot a line graph to show the time taken for the filter paper to rise against pH. [4]
(ii) Describe the relationship between pH and the time taken for the filter paper to rise. [2]

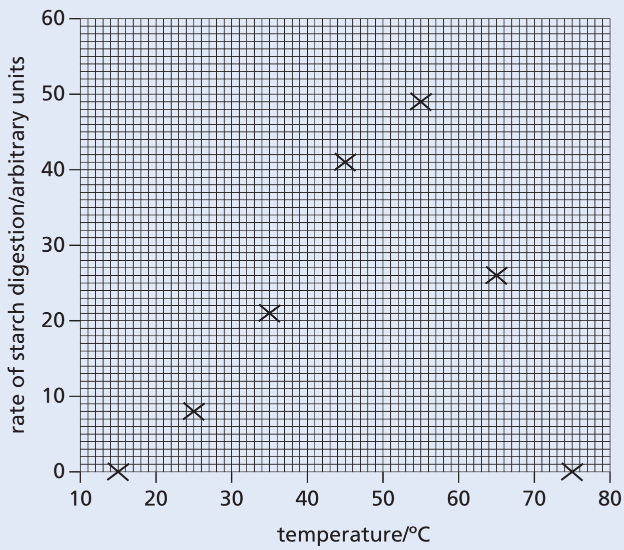
b Suggest **four** ways in which this experiment could be improved. [4]

c Suggest how this experiment could be changed to investigate the effect of temperature on the activity of catalase. [6]

[Total: 16]
(Cambridge IGCSE Biology 0610 Paper 06 Q3 November 2009)

3 a All organisms depend on enzymes. Define the term *enzyme* and describe the function of enzymes in living organisms. [3]

b Samples of an amylase enzyme were incubated with starch at different temperatures. The rate of starch digestion in each sample was recorded and points plotted on the graph shown below.



(i) Complete this line graph to show the effect of temperature on rate of digestion of starch by the amylase enzyme by adding the most appropriate line to the points. [1]

(ii) Using your graph estimate the optimum temperature for this enzyme. [1]

(iii) Suggest the rate of starch digestion at 37 °C. [1]

(iv) Describe the effect of temperature on the rate of starch digestion. [2]

(v) The enzymes originally incubated at 15 °C and 75 °C did not digest any starch. These samples were later incubated at the optimum temperature.
Predict what results could be expected in each sample and suggest reasons for your predictions. [3]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 21 Q8 June 2012)

4 Catalase is an enzyme found in plant and animal cells. It has the function of breaking down hydrogen peroxide, a toxic waste product of metabolic processes.

a (i) State the term used to describe the removal of waste products of metabolism. [1]

(ii) Define the term *enzyme*. [2]

An investigation was carried out to study the effect of pH on catalase, using pieces of potato as a source of the enzyme.
Oxygen is formed when catalase breaks down hydrogen peroxide, as shown in the equation.

$$\text{hydrogen peroxide} \xrightarrow{\text{catalase}} \text{water} + \text{oxygen}$$

The rate of reaction can be found by measuring how long it takes for 10 cm^3 oxygen to be collected.

b (i) State the independent (input) variable in this investigation. [1]

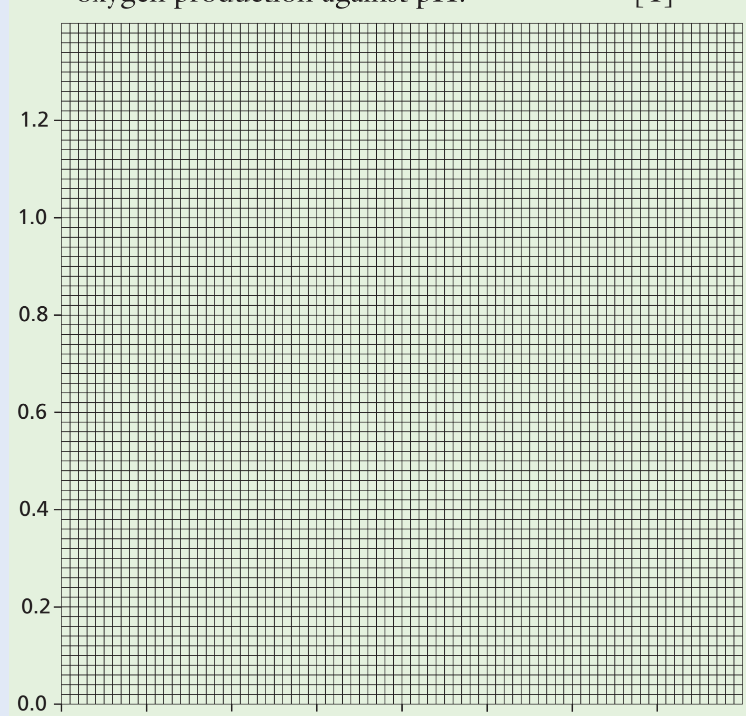
(ii) Suggest two factors that would need to be kept constant in this investigation. [2]

The table shows the results of the investigation, but it is incomplete.

pH	time to collect 10 cm^3 oxygen/min	rate of oxygen production/$cm^3\,min^{-1}$
4	20.0	0.50
5	12.5	0.80
6	10.0	1.00
7	13.6	0.74
8	17.4	

c Calculate the rate of oxygen production at pH 8. Show your working. [2]

d Complete the graph by plotting the rate of oxygen production against pH. [4]

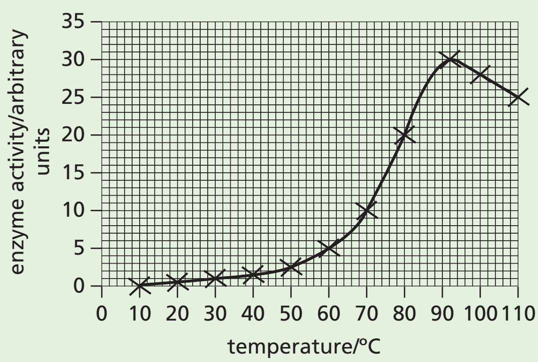


e (i) Using data from the graph, describe the changes in the reaction rate between pH4 and pH8. [2]
(ii) Explain the change in the reaction rate between pH6 and pH8. [3]

[Total: 17]

(Cambridge IGCSE Biology 0610 Paper 31 Q3 June 2008)

5 a The graph shows the activity of an enzyme produced by bacteria that live in very hot water.



Using the information in the graph, describe the effect of increasing temperature on the activity of the enzyme. [3]

Enzymes extracted from bacteria are used in biological washing powders.

b Describe how bacteria are used to produce enzymes for biological washing powder. [4]

c Food and blood stains on clothes may contain proteins and fats.
Explain how enzymes in biological washing powders act to remove food and blood stains from clothes. [4]

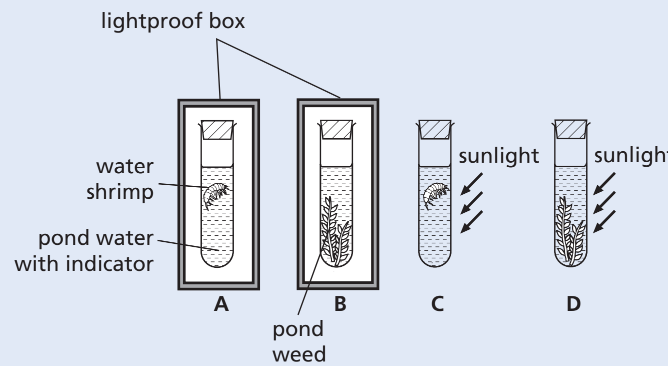
d When blood clots, an enzyme is activated to change a protein from one form into another. Describe the process of blood clotting. [3]

[Total: 14]

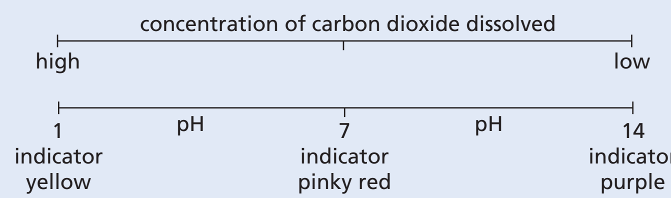
(Cambridge IGCSE Biology 0610 Paper 31 Q3 June 2009)

Plant nutrition

1 The diagram shows four test-tubes that were set up and left for 6 hours at a constant warm temperature.



Hydrogencarbonate indicator (bicarbonate indicator) changes colour depending on the pH of gases dissolved in it, as shown below.



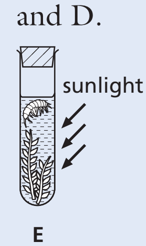
After 6 hours the colour of the indicator in all four tubes had changed.

a (i) Complete the table to predict the colour of the indicator after 6 hours. [4]

tube	colour of indicator at start	colour of indicator after 6 hours
A	pinky red	
B	pinky red	
C	pinky red	
D	pinky red	

(ii) Suggest the reason for the change in colour of the indicator in each of tubes A and D. [4]

b The diagram shows a fifth tube, E, set up at the same time and in the same conditions as tubes C and D.

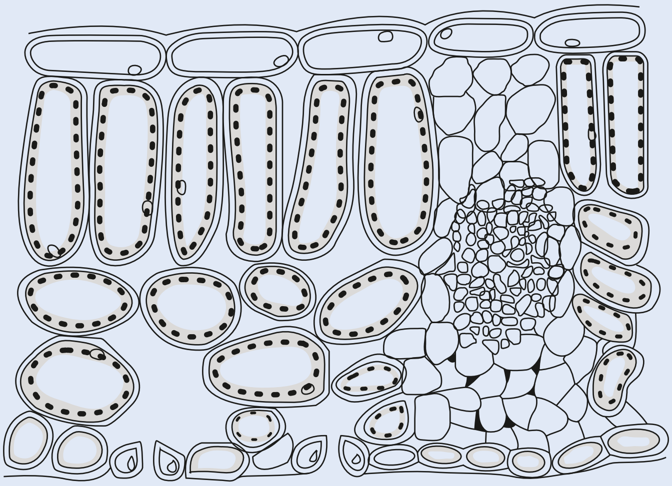


Suggest and explain the possible colour of the indicator in tube E after 6 hours. [3]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 2 Q6 June 2009)

2 The diagram shows a section through a leaf.



a On the diagram, label a stoma, the cuticle and a vascular bundle. Use label lines and the words 'stoma', 'article' and 'vascular bundle' on the diagram. [3]

b (i) The upper layers of a leaf are transparent. Suggest an advantage to a plant of this feature. [1]

(ii) The cuticle is made of a waxy material. Suggest an advantage to a plant of this feature. [1]

(iii) State **two** functions of vascular bundles in leaves. [2]

c Most photosynthesis in plants happens in leaves.

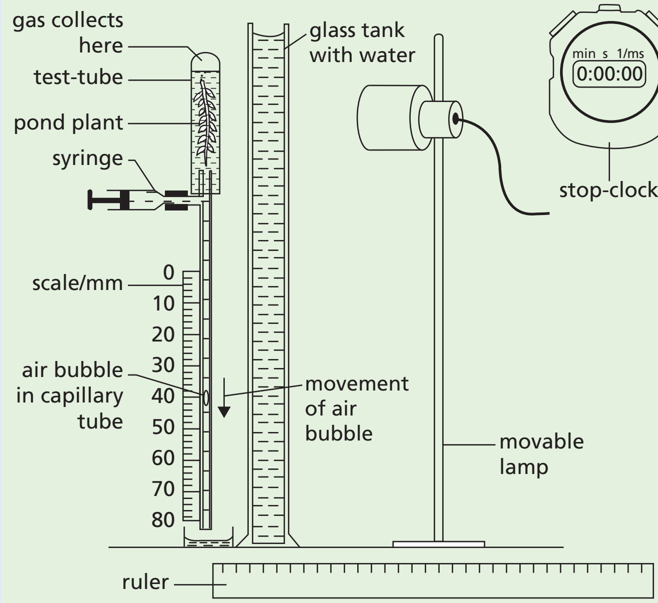
(i) Name the two raw materials needed for photosynthesis. [2]

(ii) Photosynthesis produces glucose. Describe how plants make use of this glucose. [3]

[Total: 12]

(Cambridge IGCSE Biology 0610 Paper 21 Q4 November 2010)

3 A student set up the apparatus shown in the diagram to investigate the effect of light intensity on the rate of photosynthesis of a pond plant.



The student maintained the temperature at 20 °C and measured the distance travelled by the air bubble in the capillary tube for a period of 5 minutes on three occasions for each light intensity.

The student's results are shown in the table.

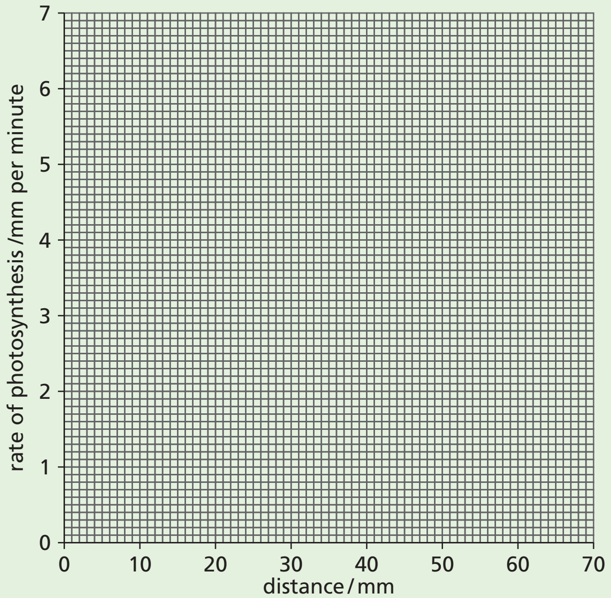
distance of lamp from pond plant/mm	distance travelled by air bubble/mm	rate of photosynthesis/ mm per minute
20	30	6.0
30	26	5.2
40	14	2.8
50	7	
60	3	0.6

a (i) Explain why the student included the glass tank and the syringe in the apparatus. [2]

(ii) Explain why the air bubble moves down the capillary tube. [3]

b (i) Calculate the rate of photosynthesis when the lamp was 50 mm from the pond plant. [1]

(ii) Plot the student's results from the table on the axes below. Draw an appropriate line on the graph to show the relationship between distance of the lamp from the pond plant and the rate of photosynthesis. [2]



c **(i)** Using the graph to help you, predict the results that the student would get if the lamp was positioned 15 mm and 70 mm from the pond plant. [2]

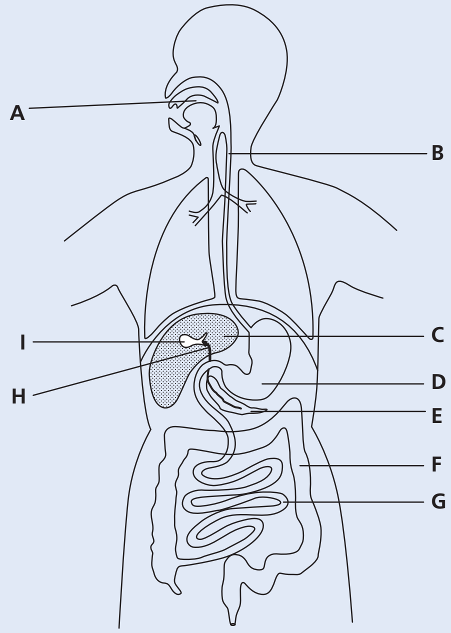
(ii) Explain why the rate of photosynthesis **decreases** as the distance of the lamp from the pond plant **increases**. [3]

[Total: 13]

(Cambridge IGCSE Biology 0610 Paper 31 Q3 November 2009)

Human nutrition

1 The diagram shows the human digestive system and associated organs.



a Use letters from the diagram to identify the structures described. Each letter may be used once, more than once, or not at all.

(i) One structure where digestion of protein occurs.

(ii) One structure where bile is stored.

(iii) One structure where peristalsis happens.

(iv) One structure where starch digestion occurs.

(v) One structure where amino acids are absorbed into the blood. [5]

b State **two** functions of each of the structures labelled C and E on the diagram.

(i) structure C [2]

(ii) structure E [2]

[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 November 2011)

2 **a** **(i)** State what is meant by the term *balanced diet*. [3]

(ii) Balanced diets should include fat, fibre, mineral salts and vitamins. Name **two** other types of nutrients that should be present in a balanced diet. [1]

b Suggest and explain the effects on a person of a diet with:

(i) too little fibre, [2]

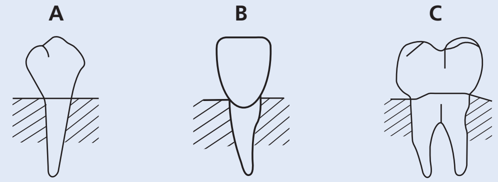
(ii) too much animal fat. [2]

c Calcium, a mineral salt, is needed in the diet. Explain the role of calcium in the body and the effect of calcium deficiency. [3]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 21 Q2 June 2011)

3 The diagram shows three different types of teeth from a human.



a **(i)** Name the types of teeth labelled A and B. [2]

(ii) State where in the jaw tooth type C is found. [1]

b Explain how regular brushing helps to prevent tooth decay. [3]

c Explain the roles of chewing and of enzymes in the process of digestion. [4]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q7 June 2010)

4 a Micronutrients are food materials that are only needed in very small quantities in the human diet. Draw one straight line from each micronutrient to its deficiency symptom. [4]

micronutrient	deficiency symptom
calcium	anaemia
vitamin C	rickets
vitamin D	scurvy
iron	

b Explain how iron, in the diet of humans, is used in the body. [3]

[Total: 7]

(Cambridge IGCSE Biology 0610 Paper 2 Q3 November 2009)

5 a Enzyme activity is vital in human digestion. Complete the table by choosing appropriate words from the list. [6]

amino acids   amylase   cellulose
fatty acids   hydrochloric acid   lipase
protein   starch   water

substrate	enzyme	product
fat		glycerol +
	protease	
		maltose

b Maltose is changed into glucose.

(i) Which part of the blood carries glucose? [1]

(ii) Which process, happening in all living cells, needs a constant supply of glucose? [1]

(iii) Excess glucose is stored. Which carbohydrate is glucose changed into for storage? [1]

(iv) Which organ is the main store of this carbohydrate? [1]

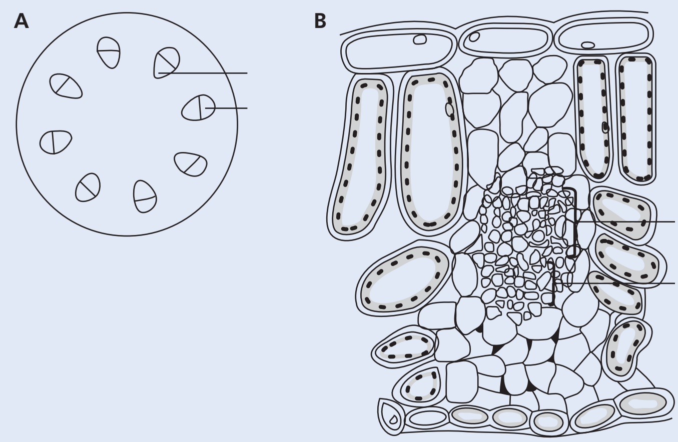
(v) Name a hormone that causes glucose to be released from storage. [1]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 2 Q4 November 2009)

Transport in plants

1 a Phloem and xylem are two types of tissue in plants. The diagram shows a section through a plant stem, **A**, and a plant leaf, **B**.



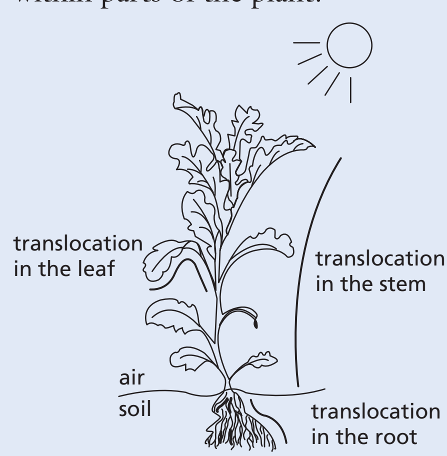
(i) Label the phloem (P) and the xylem (X) on both **A** and **B** on the diagram. Write the letters P and X on both **A** and **B**. [2]

(ii) Describe **two** functions of the xylem. [2]

b Translocation takes place in the phloem tissue.

(i) State which materials are translocated in the phloem. [2]

(ii) The diagram shows a plant in the sunlight. The three lines are arrows, with no arrow heads, showing the translocation of materials within parts of the plant.



Add arrow heads to **each** of the **three** lines to show the direction of translocation in the organs shown. [3]

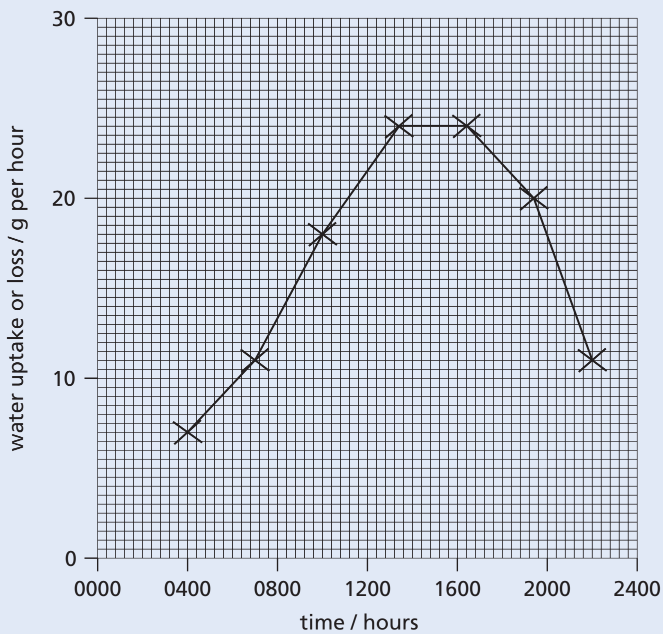
[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 June 2012)

2 An investigation of the uptake and loss of water by a plant was carried out over 24 hours. The results are shown in the table.

time of day/hours	water uptake/g per hour	water loss/g per hour
0400	7	2
0700	11	8
1000	18	24
1300	24	30
1600	24	24
1900	20	13
2200	11	5

a (i) The data for water uptake have been plotted on the grid below. Plot the data for water loss on the same grid. Label both curves. [4]



(ii) State the **two** times at which the uptake and loss of water were the same. [1]

b Explain how a **decrease** in temperature and humidity would affect the water loss by this plant.

(i) Temperature [2]

(ii) Humidity [2]

[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 21 Q6 November 2011)

3 a Explain what is meant by the term *transpiration*. [3]

b Describe the effect that **two** named environmental factors can have on the rate of transpiration. [4]

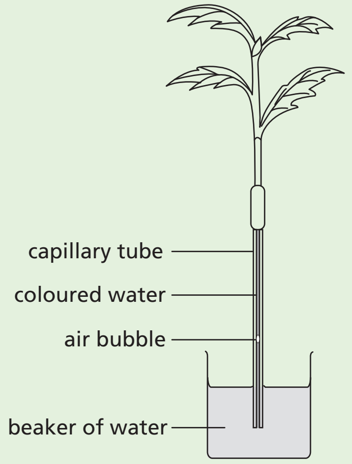
[Total: 7]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 June 2011)

4 The photograph is of a root of radish covered in many root hairs.

a Using the term *water potential*, explain how water is absorbed into root hairs from the soil. [3]

A potometer is a piece of apparatus that is used to measure water uptake by plants. Most of the water taken up by plants replaces water lost in transpiration. A student used a potometer to investigate the effect of wind speed on the rate of water uptake by a leafy shoot. As the shoot absorbs water the air bubble moves upwards. The student's apparatus is shown in the diagram.



The student used a fan with five different settings and measured the wind speed. The results are shown in the table.

wind speed/ metres per second	distance travelled by the air bubble/mm	time/minutes	rate of water uptake/mm per minute
0	4	10	0.4
2	12	5	2.4
4	20	5	4.0
6	35	5	7.0
8	40	2	

b Calculate the rate of water uptake at the highest wind speed and write your answer in the table. [1]

c Describe the effect of increasing wind speed on the rate of water uptake. You may use figures from the table to support your answer. [2]

d State **two** environmental factors, **other than wind speed**, that the student should keep constant during the investigation. [2]

e Some of the water absorbed by the plants is not lost in transpiration. State **two** other ways in which water is used. [2]

f Water moves through the xylem to the tops of very tall trees, such as the giant redwoods of North America. The movement of water in the xylem is caused by transpiration. Explain how transpiration is responsible for the movement of water in the xylem. [4]

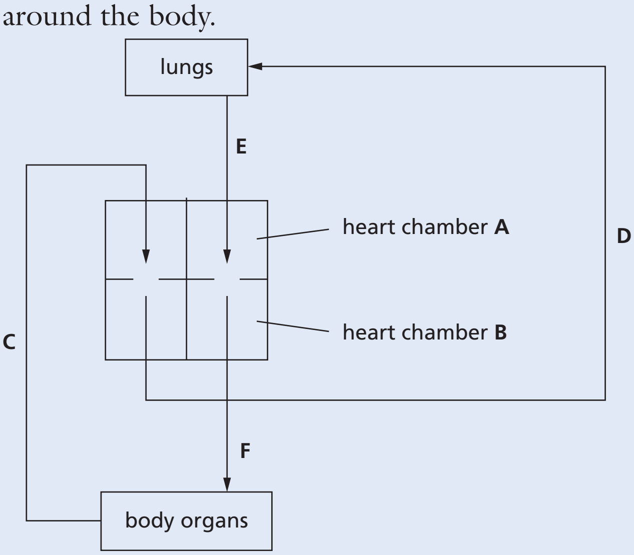
g Plants that live in hot, dry environments show adaptations for survival. State three **structural** adaptations of these plants. [3]

[Total: 17]

(Cambridge IGCSE Biology 0610 Paper 31 Q4 June 2009)

Transport in animals

1 The diagram shows the route taken by blood around the body.



a (i) Name the heart chambers **A** and **B**. [2]

(ii) Use information shown in the diagram to identify the type of blood vessel **C** as either an artery or a vein. Give a reason for your choice. [2]

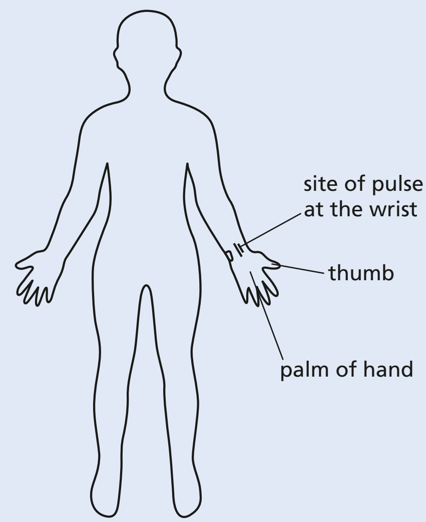
b (i) State and explain **two** differences between the contents of the blood flowing in vessels **C** and **E**. [2]

(ii) Suggest and explain which of the four blood vessels contains blood at the highest pressure. [2]

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 21 Q8 June 2010)

2 As the heart pumps blood around the human body, a pulse may be felt at certain sites, such as the one shown in the diagram.



a (i) Label on the diagram, one other site where a pulse may be felt. [1]

(ii) Suggest why it is possible to feel the pulse at these sites. [2]

b A student counted the number of pulses felt in 15 seconds at the site shown on their wrist. The student did this three times.
The results are recorded in the table.

	pulses per 15 seconds	pulses per minute
1st count	18	
2nd count	19	
3rd count	17	
mean		

(i) Complete the right-hand column in the table to show the number of pulses per minute for each count and the mean pulses per minute. [2]

(ii) Explain why it is advisable to repeat readings at least three times. [1]

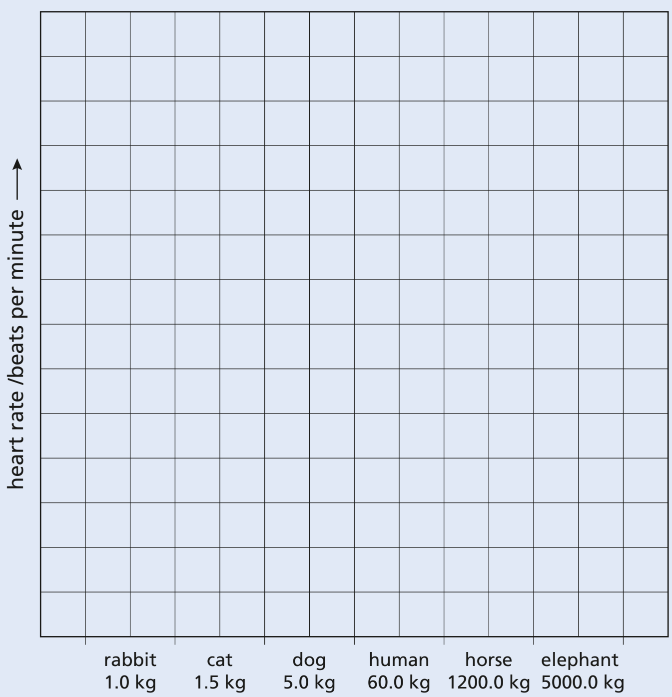
(iii) State **two** factors that may affect heart rate. For each factor explain its effect on heart rate. [4]

c Body mass and heart rates for a number of different mammals are shown in the table.

Mammal	body mass/kg	heart rate/beats per minute
rabbit	1.0	200
cat	1.5	150
dog	5.0	90
human	60.0	
horse	1200.0	44
elephant	5000.0	30

Copy the mean pulses per minute from the first table into the second table.

(i) Plot the data in a bar chart to show heart rate for all six mammals. [5]



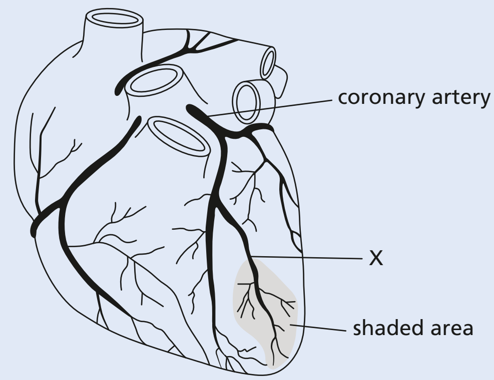
(ii) Describe the general trend shown by this data plotted on the bar chart. [1]

d An elephant can live for 70 years, a cat for 15 years and a rabbit for 9 years.
Suggest how heart rate and body mass might affect life expectancy of mammals. [1]

[Total: 17]

(Cambridge IGCSE Biology 0610 Paper 61 Q2 June 2009)

3 The diagram shows an external view of the heart.



a A blood clot is stuck at X. Explain what will happen to the heart muscle cells in the shaded area. [3]

b List **three** actions people can take to reduce the risk of having a blood clot in the coronary arteries. [3]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 21 Q3 November 2012)

4 a The human circulatory system contains valves.

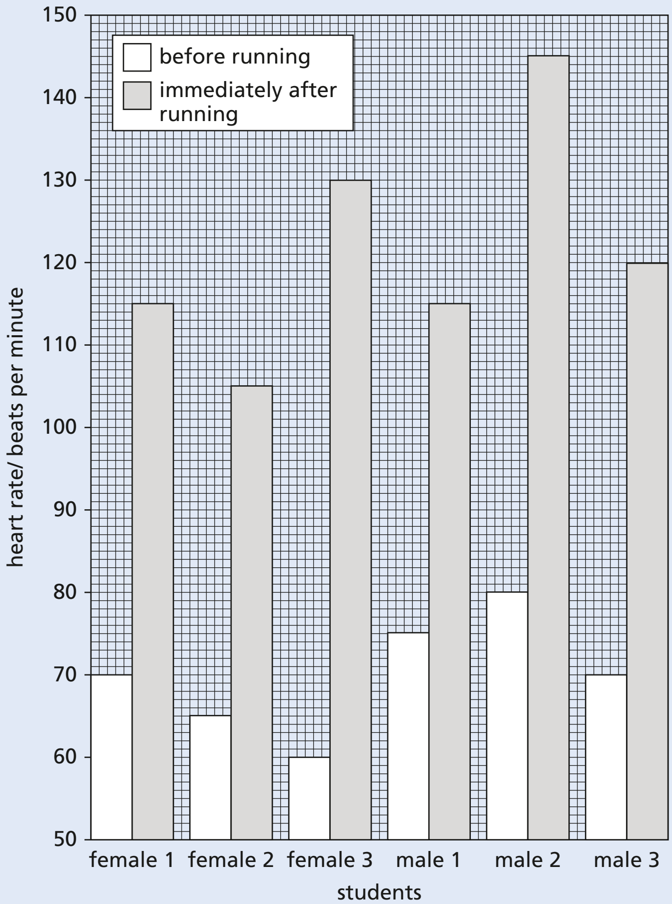
(i) State the function of these valves. [1]

(ii) Complete the table by placing a tick (✓) against **two** structures in the human circulatory system that have valves. [1]

structure in circulatory system	have valves
arteries	
capillaries	
heart	
veins	

b Describe how you would measure the heart rates of some students before they start running. [2]

c The bar chart (opposite) shows the results of an investigation of the heart rates of some students before and immediately after running. Each student ran the same distance.



(i) State which student has the lowest heart rate immediately after running. [1]

(ii) State which student has the largest change in heart rate from before to immediately after running. [1]

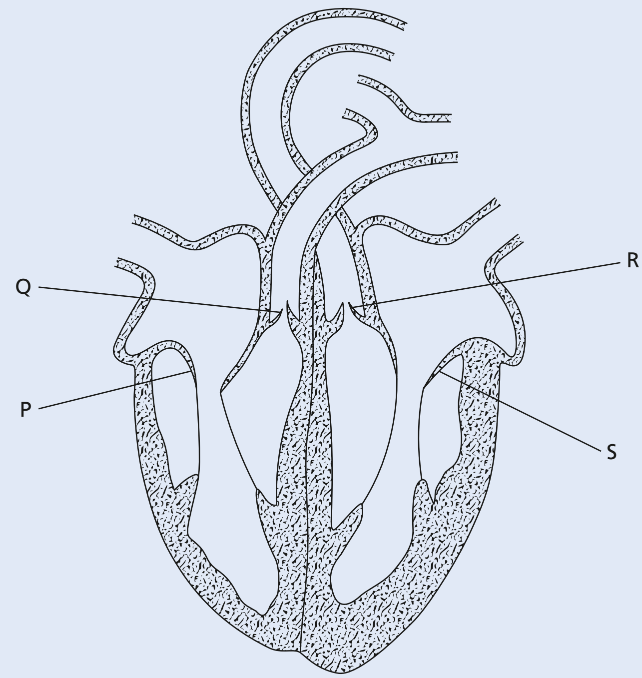
(iii) Describe any trends that you can see in the results. [2]

d Explain why heart rate changes when you run. [4]

[Total: 12]

(Cambridge IGCSE Biology 0610 Paper 21 Q2 November 2011)

5 The diagram shows a section through the heart.



a **(i)** Name the **two** blood vessels, shown on the diagram, that carry oxygenated blood. [1]

(ii) State the letter that identifies the tricuspid valve. [1]

(iii) State the letter that identifies a semilunar valve. [1]

b Describe how the heart forces blood into the aorta. [3]

c **(i)** Name the blood vessel that delivers blood to the muscles of the walls of the atria and ventricles. [1]

(ii) Name the **two** blood vessels that deliver blood to the liver. [2]

[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 21 Q8 June 2011)

Diseases and immunity

1 **a** Many communities treat their sewage and release non-polluting water into a local river. What is meant by the term *sewage*? [2]

b Sometimes the sewage treatment works cannot deal with all of the sewage and untreated material is released into the river. Suggest the likely effects of releasing untreated sewage into a river. [4]

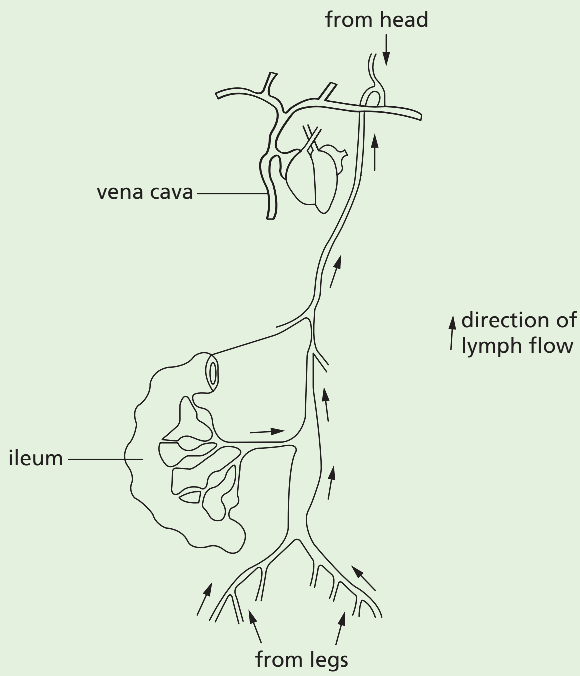
[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 2 Q2 November 2006)

2 The lymphatic system consists of:

- thin-walled lymph vessels that drain tissue fluid from many organs of the body
- lymph nodes that contain the cells of the immune system.

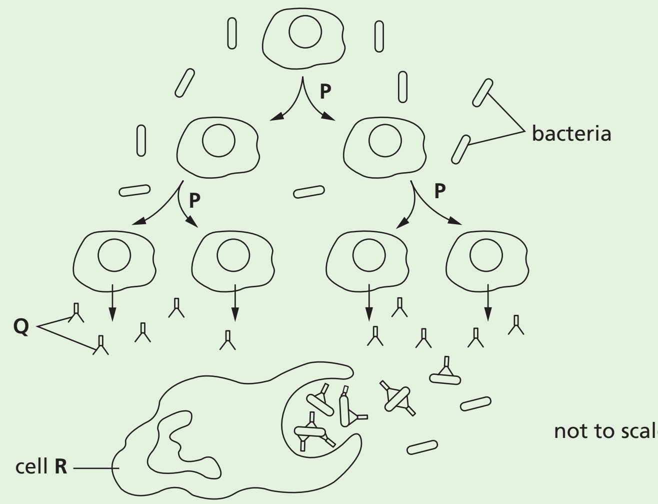
The fluid in the lymph vessels is moved in a way similar to the movement of blood in veins. The diagram shows part of the lymphatic system.



a Suggest how lymph is moved in the lymph vessels. [2]

b After a meal rich in fatty foods, the lymph leaving the ileum is full of fat droplets. Explain why there are fat droplets in the lymph leaving the ileum. [2]

Lymph flows through lymph nodes. The diagram (above right) shows the action of white blood cells in a lymph node when bacteria are present.

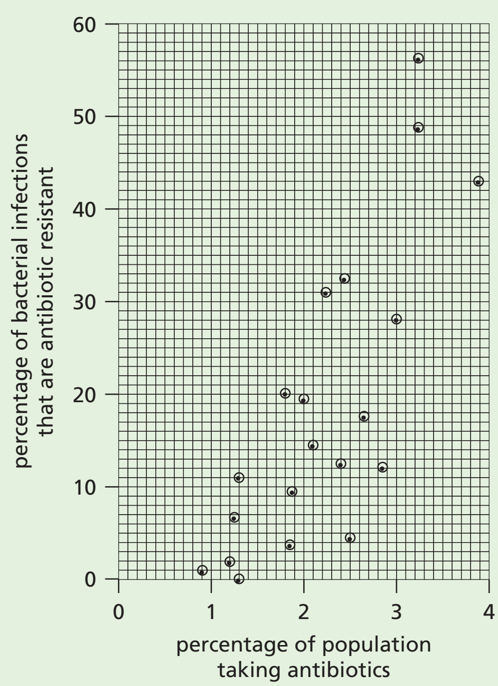


c (i) Name the type of nuclear division shown at **P** in the diagram. [1]

(ii) Name the molecules labelled **Q** in the diagram. [1]

(iii) Describe how bacteria are destroyed by cell **R**. [3]

Antibiotics are used to treat bacterial infections. An investigation was carried out into the effect of prescribing antibiotics on antibiotic resistance in 20 countries. The graph shows the results of this investigation. Each point represents the result for a country.



d Describe the results shown in the graph. Credit will be given for using figures from the graph to support your answer. [3]

e Many different antibiotics are used. Suggest why some antibiotics are used less frequently than others. [3]

[Total: 15]

(Cambridge IGCSE Biology 0610 Paper 31 Q4 November 2010)

3 a Describe the function of the immune system, including antibody production and phagocytosis. [9]

b Outline the problems of organ transplantation and how they can be overcome. [6]

[Total: 15]

(Cambridge IGCSE Biology 0610 Paper 3 Q6 November 2003)

Gas exchange in humans

1 Gaseous exchange takes place while air flows in and out of the lungs.

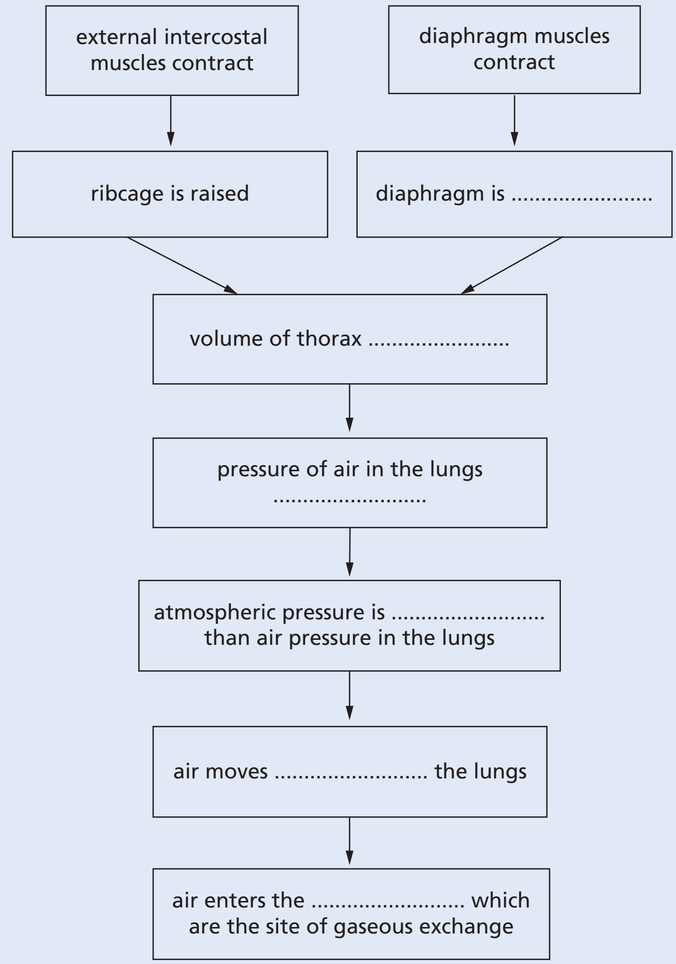
a State **three** ways in which inspired air is different from expired air. [3]

b List **three** features of gaseous exchange surfaces that help to make them more efficient. [3]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 21 Q8 November 2009)

2 The ribcage and diaphragm are involved in the breathing mechanism to ventilate the lungs. The flow chart shows the changes that take place when breathing in.



a Complete the flow chart by writing appropriate words in the spaces provided. [6]

b The photograph shows part of the epithelium that lines the trachea.

Explain how the cells labelled A and B in the photograph protect the gas exchange system. [4]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 31 Q3 November 2012)

3 a Define the term *aerobic respiration.* [2]

During exercise the movement of the ribcage enables air to enter the lungs.

b Describe how the ribcage is moved during inspiration (breathing in) and explain how this causes air to enter the lungs. [4]

c Explain how the ribcage returns to its resting position during expiration (breathing out). [2]

Some students carried out an investigation on a 16-year old athlete. The table shows the results of their investigation on the athlete's breathing at rest and immediately after 20 minutes of running.

Ventilation rate is the volume of air taken into the lungs per minute.

	at rest	**immediately after 20 minutes of running**
rate of breathing/breaths per minute	12	20
average volume of air taken in with each breath/dm^3	0.5	3.5
ventilation rate/dm^3 per minute	6.0	

d (i) Calculate the ventilation rate of the athlete immediately after 20 minutes of running. [1]

(ii) Explain why the athlete has a high ventilation rate **after the exercise has finished**. [5]

[Total: 14]

(Cambridge IGCSE Biology 0610 Paper 31 Q3 November 2010)

Respiration

1 a (i) State the word equation for aerobic respiration. [2]

(ii) Complete the table to show three differences between aerobic respiration and anaerobic respiration in humans. [3]

	aerobic respiration in humans	**anaerobic respiration in humans**
1		
2		
3		

b Yeast is used in making some types of bread and in brewing.

(i) Explain the role of yeast in bread-making. [3]

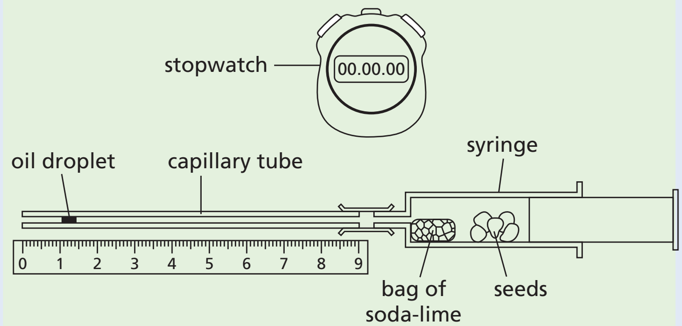
(ii) Explain the role of yeast in brewing. [2]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q5 November 2010)

2 a State, using chemical symbols, the equation for aerobic respiration. [3]

A student compared the respiration of germinating mung bean seeds with pea seeds using the apparatus shown in the diagram.



The soda-lime absorbs any carbon dioxide released by the germinating seeds. The student recorded the position of the oil droplet every minute over a period of 6 minutes.

b State **three** variables that should be kept constant in this investigation. [3]

c The table shows the student's results.

time/ minute	**germinating mung bean seeds**		**germinating pea seeds**	
	position of droplet/mm	**distance moved/mm per minute**	**position of droplet/mm**	**distance moved/mm per minute**
0	0	0	0	0
1	12	12	10	10
2	23	11	19	9
3	36	13	28	9
4	45	9	33	5
5	48	3	36	3
6	48	0	36	0

(i) State which way the droplet moves **and** explain your answer. [3]

(ii) State what happens to the movement of the droplet after 3 minutes **and** suggest an explanation. [2]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 31 Q3 November 2011)

Excretion in humans

1 a The kidney is an excretory organ.
Name **two** other excretory organs in humans and in each case state a substance that the organ excretes. [4]

b The table shows the amounts of some substances in the blood in the renal artery and in the renal vein of a healthy person.

substance	amount in blood in renal artery (arbitrary units)	amount in blood in renal vein (arbitrary units)
oxygen	100.0	35.0
glucose	10.0	9.7
sodium salts	32.0	29.0
urea	3.0	0.5
water	180.0	178.0

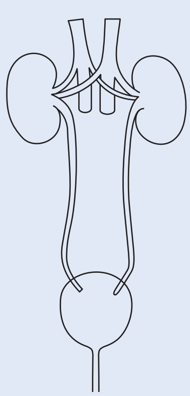
Suggest what happens in the kidney to bring about the differences in the composition of the blood shown in the table. [4]

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 November 2010)

2 a Why do most waste products of metabolism have to be removed from the body? [1]

b The diagram shows the human excretory system.



Name the parts that fit each of the following descriptions.

(i) The tube that carries urine from the kidneys. [1]

(ii) The organ that stores urine. [1]

(iii) The blood vessel that carries blood away from the kidneys. [1]

c Outline how the kidneys remove only waste materials from the blood. [3]

d Excess amino acids cannot be stored in the body and have to be broken down.

(i) Where are excess amino acids broken down? [1]

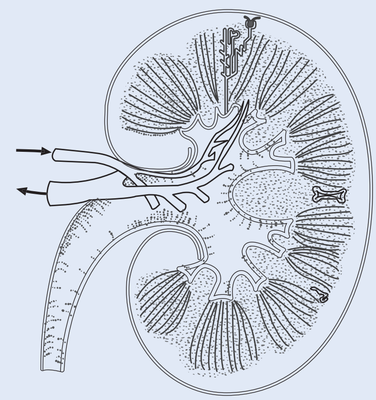
(ii) Which waste chemical is formed from the breakdown of excess amino acids? [1]

[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 2 Q2 June 2009)

3 a Define the term *excretion*. [3]

b The figure below shows a section through a kidney.



(i) Using label lines and the letters given, label the following on a copy of the figure:

F where filtration occurs

R the renal artery

U where urine passes to the bladder [3]

(ii) Describe the process of filtration in the kidney. [3]

(iii) Name the processes resulting in the reabsorption of

1 glucose

2 water. [3]

[Total: 12]

(Cambridge IGCSE Biology 0610 Paper 3 Q3 November 2007)

Co-ordination and response

1 a Define the term *homeostasis*. [2]

b It has been suggested by some scientists that the iris reflex is an example of homeostasis. Describe this reflex and explain why it might be considered to be a homeostatic mechanism. [3]

[Total: 5]

(Cambridge IGCSE Biology 0610 Paper 21 Q10 June 2008)

2 a Complete the following paragraph using appropriate words.

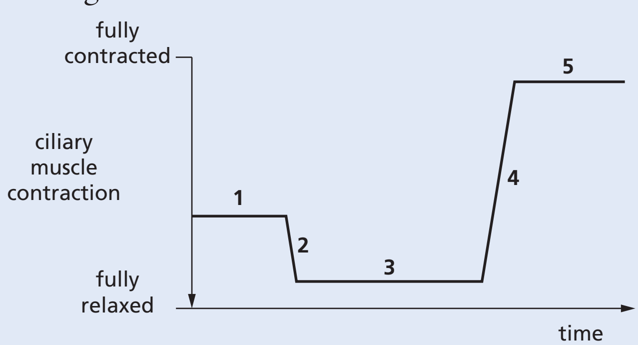
Sense organs are composed of groups of ____________ cells that respond to specific ____________. The sense organs that respond to chemicals are the ____________ and the ____________. [4]

b The eye is a sense organ that focuses light rays by changing the shapes of its lens. It does this by contracting its ciliary muscles.

(i) What links the ciliary muscles to the lens? [1]

(ii) Describe the change in shape of the lens when a person looks from a near object to a distant object. [1]

c The graph shows changes in the contraction of the ciliary muscles as a person watches a humming bird move from flower to flower while feeding on nectar.



In which period of time, 1, 2, 3, 4 or 5, was the bird

(i) feeding from a flower very near to the person [1]

(ii) flying away from the person [1]

(iii) flying towards the person. [1]

[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 21 Q7 June 2009)

3 a Name **two** sense organs and an environmental stimulus that each detects. [2]

b (i) Tropisms occur in plants. State the meaning of the term *tropism*. [2]

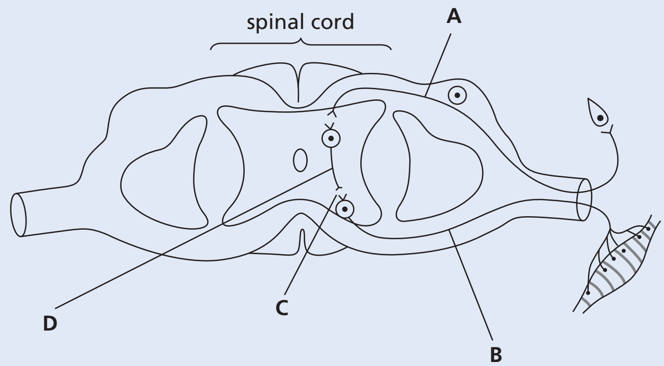
(ii) Complete the table about tropisms in plants. [4]

stimulus	name of tropism	effect on plant shoot
gravity		
light		

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 June 2010)

4 a The diagram shows the structures involved in a reflex arc.



(i) On the diagram label structures **A**, **B**, **C** and **D**. [4]

(ii) Name the two types of tissue in the body that can act as effectors. [2]

b (i) Describe the characteristics of a reflex action resulting from the activity of structures **A**, **B**, **C** and **D**. [2]

(ii) State **one** example of a reflex action. [1]

[Total: 9]

(Cambridge IGCSE Biology 0610 Paper 21 Q4 June 2011)

5 a Plants, like animals, respond to stimuli. Tropisms are an example of a plant response.

(i) Define the term *geotropism*. [2]

(ii) Suggest the advantages of geotropic responses for a seed germinating in the soil. [3]

b State three external conditions necessary for the germination of a seed in the soil. [3]

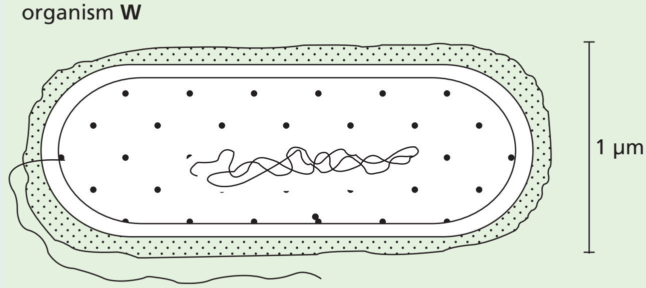
[Total: 8]

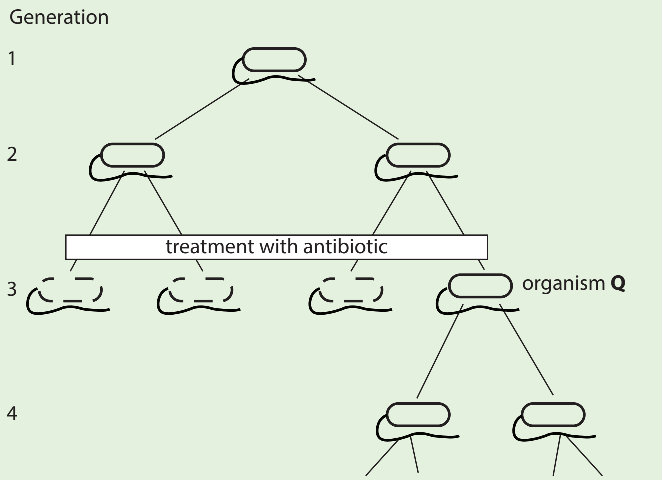
(Cambridge IGCSE Biology 0610 Paper 21 Q3 November 2011)

Drugs

1 The first diagram shows an organism **W** and the second diagram shows how the reproduction of this organism is affected by an antibiotic.

organism **W**





a (i) What type of organism is **W** most likely to be? [1]

(ii) State **three** reasons for your answer. [3]

b Name the type of reproduction shown by organism **W**. [1]

Q is the only organism surviving the antibiotic treatment.

c Suggest an explanation for the survival of **Q** and its offspring. [2]

d Explain why patients who are treated with antibiotics are always advised to take a complete course of treatment, rather than stop the treatment as soon as they feel better. [3]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 3 Q9 June 1998)

Reproduction

1 Choose words from the list to complete each of the spaces in the paragraph.

Each word may be used once only and some words are not used at all.

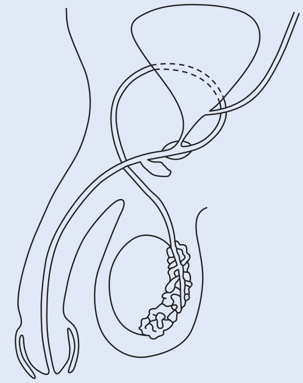
bright dry dull heavy large
light sepals small stamens
sticky style

Flowers of plants that rely on the wind to bring about pollination tend to have ____________ petals that have a ____________ colour. Their pollen is normally ____________ and ____________. In these flowers, the ____________ and the ____________ both tend to be long. [6]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 21 Q2 June 2008)

2 The diagram shows the male reproductive system.



a Using a label line and the letters given, label the diagram.

(i) **G** where gametes are formed [1]

(ii) **S** the sperm duct [1]

(iii) **T** where testosterone is formed [1]

(iv) **U** the urethra [1]

b Describe **two** secondary characteristics regulated by testosterone. [2]

c Choose words from the list to complete each of the spaces in the paragraph. Each word may be used once only and some words may not be used at all.

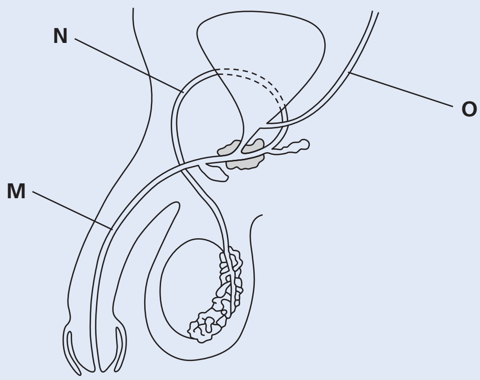
four diploid double half
haploid meiosis mitosis two

Gametes are formed by the division of a nucleus, a process called ____________. This process produces a total of ____________ cells from the original cell. Each of these cells has a nucleus described as being ____________ and each nucleus contains ____________ the number of chromosomes present in the original nucleus. [4]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q8 June 2009)

3 The diagram shows a section through parts of the male reproductive and urinary systems.



a (i) Name the tubes labelled **M**, **N** and **O**. [3]
(ii) Explain the roles of the testes, the prostate gland and the scrotum. [4]

b Humans use a variety of methods of birth control.
(i) On the diagram, put an **X** where a vasectomy could be carried out. [1]
(ii) Explain **one** method of birth control, used by males, that can also protect against infection by a sexually transmitted disease. [2]
(iii) Name **one** sexually transmitted disease. [1]

[Total: 11]

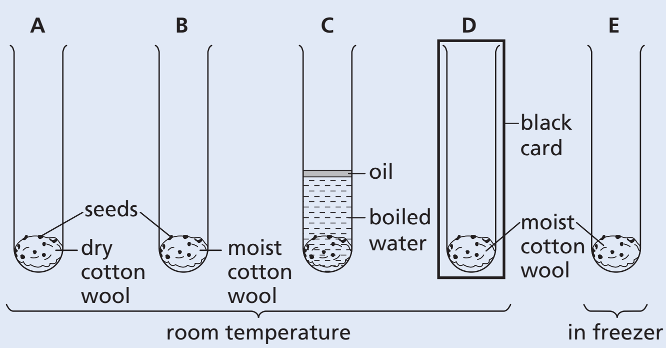
(Cambridge IGCSE Biology 0610 Paper 21 Q3 June 2011)

4 Reproduction in humans is an example of sexual reproduction. Outline what occurs during:
a sexual intercourse [2]
b fertilisation [3]
c implantation. [2]

[Total: 7]

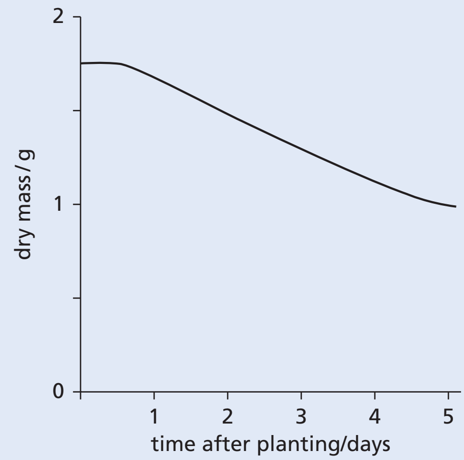
(Cambridge IGCSE Biology 0610 Paper 21 Q8 Nov 2011)

5 The diagram shows an experiment to investigate the conditions needed for germination. Tubes A, B, C and D are at room temperature and tube E is in a freezer.



a State **three** of the environmental conditions this experiment is investigating. [3]
b Predict in which **two** tubes the seeds will germinate. [2]
c Nuclear and cell division happen during germination.
(i) Name the type of nuclear division that takes place during the growth of a seedling. [1]
(ii) State how the number of chromosomes in each of the new cells compares with the number of chromosomes in the original cells. [1]

d The graph shows the changes in the dry mass of a broad bean seed in the first 5 days after planting.



Describe and suggest an explanation for the changes that happen to the dry mass of the seed in the first 5 days after planting. [3]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q5 June 2010)

6 a Using straight lines, match the names of flower parts with their functions. One has been completed for you. [4]

anther	allows the passage of the pollen tube to the ovary
petal	attracts insects for pollination
sepal	produces pollen grains
style	protects the flower when in bud
stigma	the surface on which the pollen lands during pollination

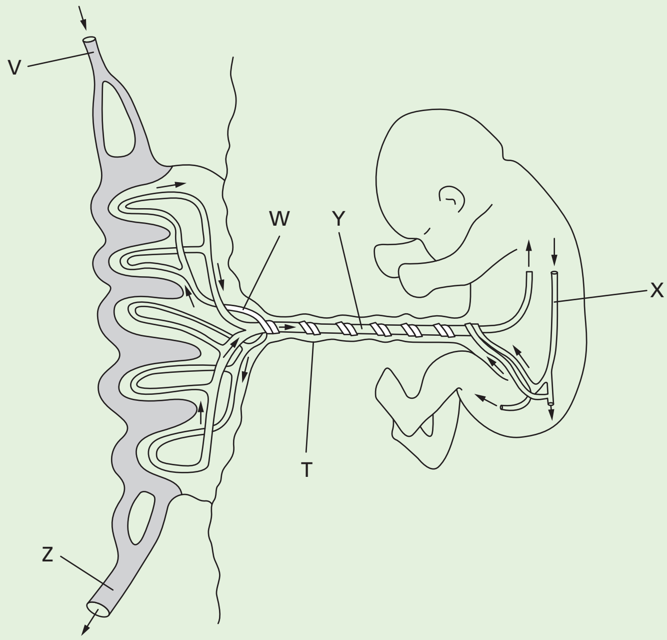
b Describe how the stigmas of wind-pollinated flowers differ from the stigmas of insect-pollinated flowers. Relate these differences to the use of wind as the pollinating agent. [3]

c Discuss the implication to a species of self-pollination. [3]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 31 Q1 June 2008)

7 The diagram shows the structure of the placenta and parts of the fetal and maternal circulatory systems.



a (i) Complete the table by listing the blood vessels that carry oxygenated blood. Use the letters in the diagram to identify the blood vessels. [2]

circulatory system	blood vessels that carry oxygenated blood
maternal	
fetal	

(ii) Name structure **T** and describe what happens to it after birth. [2]

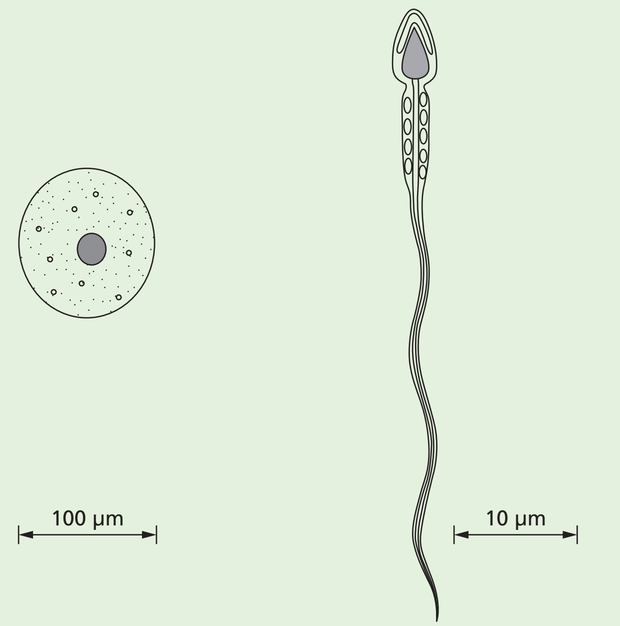
(iii) The placenta is adapted for the exchange of substances between the maternal blood and the fetal blood. Describe the exchanges that occur across the placenta to keep the fetus alive and well. [4]

b The placenta secretes the hormones oestrogen and progesterone. Describe the roles of these hormones during pregnancy. [3]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 31 Q5 June 2012)

8 The diagram shows a human egg cell and a human sperm cell.



human egg cell human sperm cell

a (i) What is the name given to the release of eggs from the ovary? [1]

(ii) Sperm cells and egg cells are haploid. State the meaning of the term *haploid*. [1]

b Complete the table to compare egg cells with sperm cells. [4]

feature	egg cells	sperm cells
site of production		
relative size		
numbers produced		
mobility		

c Three hormones that control the menstrual cycle are:

- follicle stimulating hormone (FSH)
- luteinising hormone (LH)
- oestrogen.

(i) Name the site of production and release of oestrogen. [1]

(ii) Describe the role of oestrogen in controlling the menstrual cycle. [2]

d Artificial insemination is sometimes used as a treatment for female infertility. Outline how artificial insemination is carried out in humans. [2]

[Total: 11]

(Cambridge IGCSE Biology 0610 Paper 31 Q3 June 2010)

Inheritance

1 Flowers from three red-flowered plants, **A**, **B** and **C**, of the same species were self-pollinated.

a Explain what is meant by the term *pollination*. [2]

b Seeds were collected from plants **A**, **B** and **C**. The seeds were germinated separately and were allowed to grow and produce flowers. The colour of these flowers is shown in the table.

seeds from plant	colour of flowers grown from the seeds
A	all red
B	some red and some white
C	some red and some white

(i) State the recessive allele for flower colour. [1]

(ii) State which plant, **A**, **B**, or **C**, produced seeds that were homozygous for flower colour. [1]

(iii) Suggest how you could make certain that self-pollination took place in the flowers of plants **A**, **B** and **C**. [2]

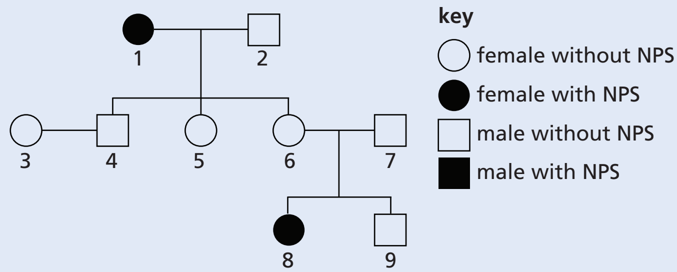
c Complete the genetic diagram to explain how two red-flowered plants identical to plant **B** could produce both red-flowered and white-flowered plants. Use the symbols **R** to represent the dominant allele and **r** to represent the recessive allele. [4]

	parent 1		parent 2
parental phenotypes	red-flowered	×	red-flowered
parental genotypes		×	
gametes	○ ○	+	○ ○
offspring genotypes			
offspring phenotypes			

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q10 November 2011)

2 The diagram shows a family tree for a condition known as nail-patella syndrome (NPS).



a (i) State whether NPS is controlled by a dominant or a recessive allele.

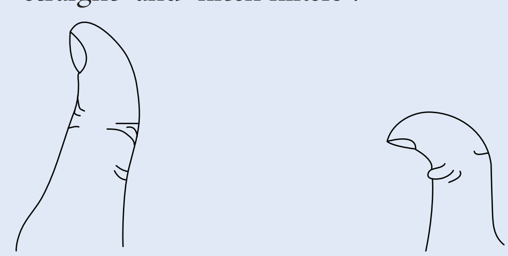
(ii) Explain which evidence from the family tree confirms your answer to **(i)**. [3]

b Explain what the chances are for a third child of parents 6 and 7 having NPS. You may use a genetic diagram to help your explanation. [3]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 21 Q7 June 2008)

3 There is a variation in the shape of human thumbs. The diagram shows the two forms referred to as 'straight' and 'hitch hikers'.



straight hitch hikers

A survey of thumb shapes was carried out on 197 students. The results are shown in the table.

age/years	number of students with 'straight' thumbs		number of students with 'hitch hiker' thumbs	
	male	female	male	female
12	21	24	4	2
13	18	28	3	5
14	19	15	2	3
15	26	20	3	4
total	84	87	12	14

a Describe the results shown in the table. [3]

b Scientists think that thumb shape is controlled by a single gene. What evidence is there from the table to support this idea? [3]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 61 Q3 November 2010)

4 Complete the sentences by writing the most appropriate word in each space. Use only words from the list below.

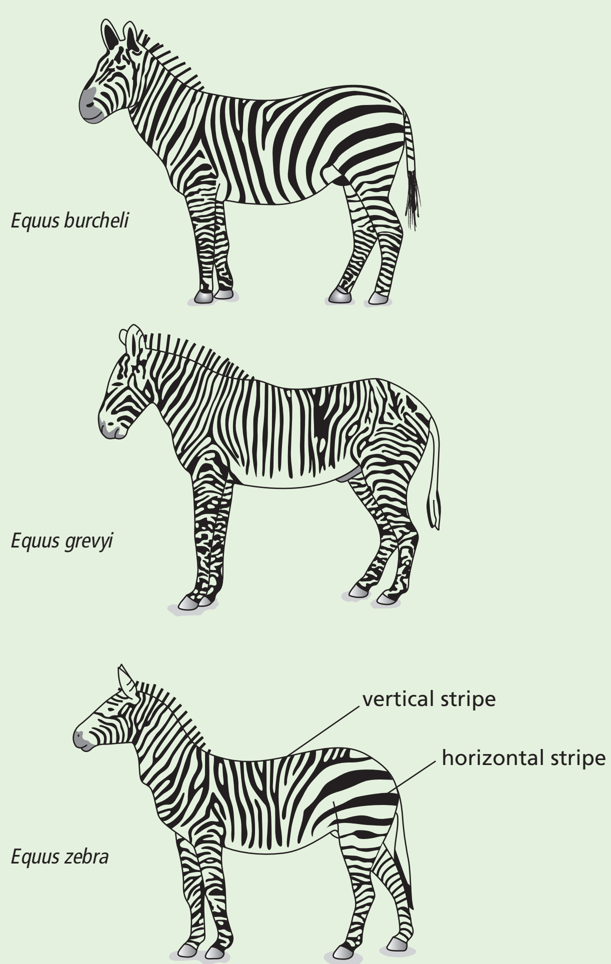
allele diploid dominant gene genotype
haploid heterozygous homozygous meiosis
mitosis phenotype recessive

Wing length in the fruit fly, *Drosophila*, is controlled by a single ______ that has two forms, one for long and one for short wings. The sperm and ova of fruit flies are produced by the process of ______. When fertilisation occurs the gametes fuse to form a ______ zygote. When two long-winged fruit flies were crossed with each other some of the offspring were short-winged. The ______ of the rest of the offspring was long-winged. The short-winged form is ______ to the long-winged form and each of the parents must have been ______. [6]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 21 Q6 November 2010)

5 The diagram shows three species of zebra.



a Describe one method a scientist could use to show that zebras shown in the diagram are different species. [1]

b Studies have shown that the hotter the environment, the more stripes zebras have.

(i) State the type of variation which would result in different numbers of stripes. [1]

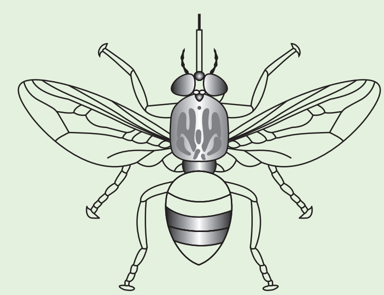
(ii) Study the diagram. Suggest which species of zebra lives in the hottest environment. [1]

c Occasionally, zebras are born that are almost completely black. The change in appearance is the result of mutation.

(i) State the term that is used to describe the appearance of an organism. [1]

(ii) Define the term *mutation*. [2]

d Tsetse flies attack animals with short fur, sucking their blood and spreading diseases. The diagram shows a tsetse fly. This fly is an insect, belonging to the arthropod group.



(i) State **one** feature, visible in the diagram, which is common to all arthropods. [1]

(ii) State **two** features, visible in the diagram, which distinguish insects from other arthropod groups. [2]

e Scientists have discovered that zebras with more horizontal stripes attract fewer tsetse flies.

(i) Suggest why the stripes on the head and neck of the zebra would be an advantage when it feeds on the grass on the ground. [2]

(ii) Describe how a species of zebra could gradually develop more horizontal stripes. [3]

[Total: 14]

(Cambridge IGCSE Biology 0610 Paper 31 Q4 June 2008)

6 The flowers of pea plants, *Pisum sativum*, are produced for sexual reproduction. The flowers are naturally self-pollinating, but they can be cross-pollinated by insects.

a Explain the difference between self-pollination and cross-pollination. [2]

b Explain the disadvantages for plants, such as *P. sativum*, of reproducing sexually. [4]

Pea seeds develop inside pea pods after fertilisation. They contain starch. A gene controls the production of an enzyme involved in the synthesis of starch grains. The allele, R, codes for an enzyme that produces normal starch grains. This results in seeds that are round. The allele, r, does not code for the enzyme. The starch grains are not formed normally. This results in seeds that are wrinkled. The diagram shows round and wrinkled pea seeds.

round pea seed   wrinkled pea seed

Pure bred plants are homozygous for the gene concerned. A plant breeder had some pure bred pea plants that had grown from round seeds and some pure bred plants that had grown from wrinkled seeds.

c State the genotypes of the pure bred plants that had grown from round and from wrinkled seeds. [1]

These pure bred plants were cross-pollinated (cross 1) and the seeds collected. All the seeds were round. These round seeds were germinated, grown into adult plants (offspring 1) and self-pollinated (cross 2). The pods on the offspring 1 plants contained both round and wrinkled seeds. Further crosses (3 and 4) were carried out as shown in the table.

cross		phenotype of seeds in the seed pods		ratio of round to wrinkled seeds
		round seeds	wrinkled seeds	
1	pure bred for round seeds x pure bred for wrinkled seeds	✓	✗	1 : 0
2	offspring 1 self-pollinated	✓	✓	
3	offspring 1 x pure bred for round seeds			
4	offspring 1 x pure bred for winkled seeds			

d Complete the table by indicating
- the type of seeds present in the pods with a tick [✓] or a cross [✗]
- the ratio of round to wrinkled seeds. [3]

e Seed shape in peas is an example of discontinuous variation. Suggest **one** reason why seed shape is an example of discontinuous variation. [1]

Plants have methods to disperse their seeds over a wide area.

f Explain the **advantages** of having seeds that are dispersed over a wide area. [3]

[Total: 14]

(Cambridge IGCSE Biology 0610 Paper 31 Q6 November 2012)

Variation and selection

1 One variety of the moth, *Biston betularia*, has pale, speckled wings. A second variety of the same species has black wings. There are no intermediate forms. Equal numbers of both varieties were released into a wood made up of trees with pale bark. Examples of these are shown in the diagram.

After 2 weeks as many of the moths were caught as possible. The results are shown in the table.

wing colour of moth	number released	number caught
pale, speckled	100	82
black	100	36

a (i) Suggest and explain **one** reason, related to the colour of the bark, for the difference in numbers of the varieties of moth caught. [1]

(ii) Suggest and explain how the results may have been different if the moths had been released in a wood where the trees were blackened with carbon dust from air pollution. [2]

The table below shows the appearance and genetic make-up of the different varieties of this species.

wing colour	genetic make-up
pale, speckled	GG; Gg
black	gg

b (i) State the appropriate terms for the table headings. [2]

(ii) State and explain which wing colour is dominant. [2]

c State the type of genetic variation shown by these moths. Explain how this variation is inherited. [3]

d Heterozygous moths were interbred. Use a genetic diagram to predict the proportion of black-winged moths present in the next generation. [5]

e (i) Name the process that can give rise to different alleles for wing colour in a population of moths. [1]

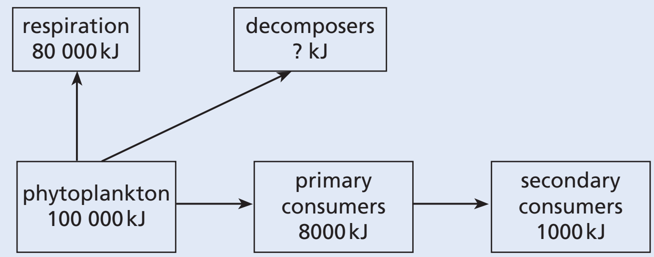
(ii) Suggest **one** factor which might increase the rate of this process. [1]

[Total: 17]

(Cambridge IGCSE Biology 0610 Paper 31 Q5 June 2007)

Organisms and their environment

1 a The chart shows the flow of some of the energy through a food chain in an ocean.



About 1% of the light energy reaching the ocean is converted to chemical energy by the phytoplankton. The phytoplankton produce sugars, fats and proteins.

(i) Name the process that changes light energy to chemical energy. [1]

(ii) Name the chemical in the phytoplankton that absorbs light energy. [1]

(iii) Calculate, using information from the flow chart, how much energy passes from the phytoplankton to the decomposers. [1]

(iv) Name **two** groups of decomposers. [2]

(v) Calculate, using information from the flow chart, the percentage of energy passed from the phytoplankton to the primary consumers. [2]

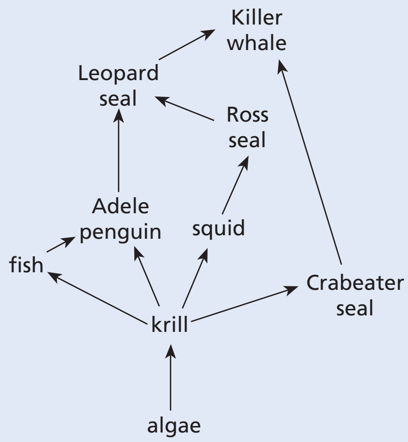
(vi) About 88% of the energy in the primary consumers does not become part of the secondary consumers. Explain how this energy is lost from the food chain. [3]

b The organisms in this food chain form a community in the ocean. This community is formed of many populations. Explain what is meant by the term *population*. [2]

[Total: 12]

(Cambridge IGCSE Biology 0610 Paper 21 Q6 June 2011)

2 The diagram shows part of a food web for the South Atlantic Ocean.



a **(i)** Name the top carnivore in this food web. [1]

(ii) Name a member of this food web that is both a secondary and a tertiary consumer. [1]

b Use the information from the food web to complete the food chain of five organisms.

algae ⟶ ____________ ⟶ ____________ ⟶ ____________ ⟶ ____________ [2]

c In the future the extraction of mineral resources in the Antarctic might occur on a large scale. This could destroy the breeding grounds of the Ross seal.

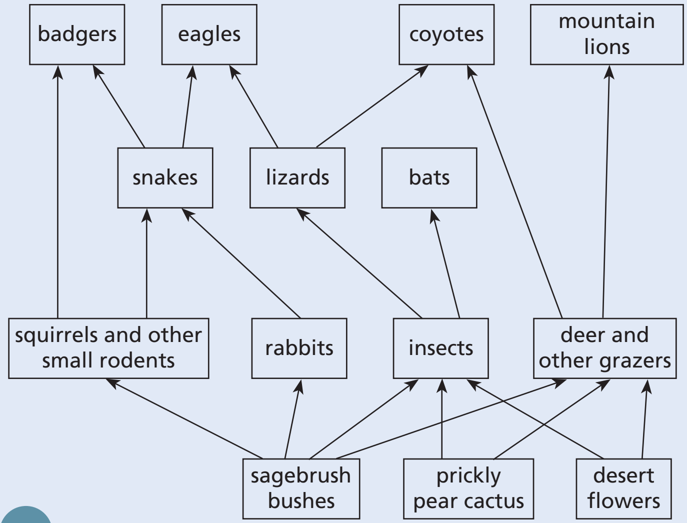
(i) State and explain what effects this might have on the population of Leopard seal. [2]

(ii) State and explain what effects this might have on the population of fish. [4]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 June 2008)

3 The diagram shows a food web.



a Explain the difference between a food web and a food chain. [2]

b From the food web name:

(i) a carnivore

(ii) a producer

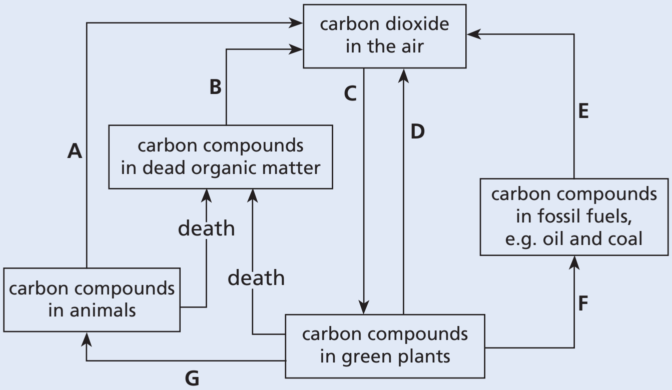
(iii) a consumer from the 2nd trophic level. [3]

c In some regions, mountain lions have been hunted and face extinction. Suggest how the coyotes might be affected if the mountain lion became extinct. [3]

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 November 2012)

4 The diagram shows a carbon cycle.



a **(i)** Name the process represented by arrow **A**. [1]

(ii) Name the process represented by arrow **E**. [1]

b **(i)** Name **one** group of organisms responsible for process **B**. [1]

(ii) List **two** environmental conditions needed for process **B** to occur. [2]

c **(i)** Which arrow represents photosynthesis? [1]

(ii) Complete the word equation for photosynthesis.

____________ + ____________ ⟶

oxygen + ____________ [2]

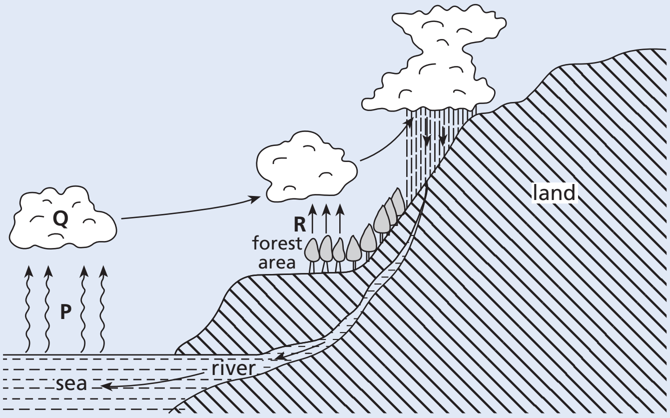
(iii) This process needs a supply of energy. Name the form of energy needed. [1]

d In an ecosystem the flow of carbon can be drawn as a cycle but the flow of energy cannot be drawn as a cycle. Explain this difference. [3]

[Total: 12]

(Cambridge IGCSE Biology 0610 Paper 21 Q5 November 2012)

5 The diagram shows the water cycle.



a (i) The arrows labelled **P** represent evaporation. Which type of energy is needed for this process? [1]

(ii) State what causes the formation of clouds at **Q**. [1]

b (i) What process is represented by the arrows labelled **R**? [1]

(ii) Name **three** factors that could alter the rate at which process **R** happens. [3]

c A logging company wants to cut down the forest area.

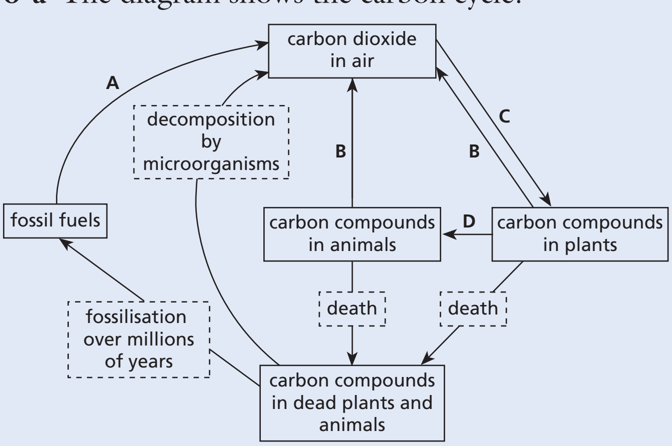
(i) Suggest what effects this deforestation might have on the climate further inland. Explain your answer. [2]

(ii) State **two** other effects deforestation could have on the environment. [2]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 2 Q4 June 2009)

6 a The diagram shows the carbon cycle.



(i) Name the processes that cause the changes shown by the arrows. [4]

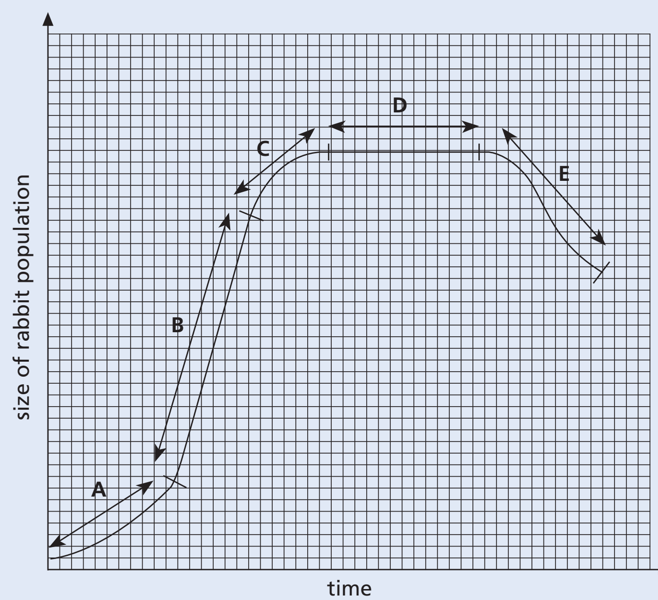
(ii) Name **one** type of organism that brings about decomposition. [1]

b Over the last few decades, the carbon dioxide concentration in the atmosphere has been rising. Suggest how this has happened. [3]

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 21 Q7 November 2008)

7 Rabbits are primary consumers. The graph shows changes in the population of rabbits after a small number were released on an island where none had previously lived.



a Which stage, **A**, **B**, **C**, **D** or **E**, shows when the birth rate was

(i) equal to the death rate [1]

(ii) slightly greater than the death rate? [1]

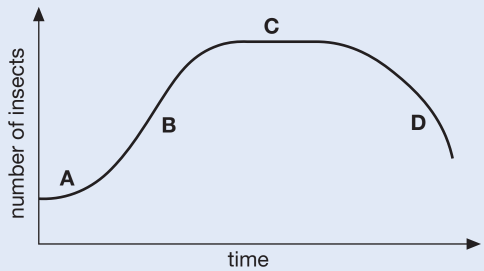
b (i) Suggest **two** factors that allowed the change in the rabbit population during stage **B**. [2]

(ii) Suggest **two** reasons for the change in the rabbit population during stage **E**. [2]

[Total: 6]

(Cambridge IGCSE Biology 0610 Paper 2 Q5 November 2009)

8 The graph shows a population growth graph for a herbivorous insect that has just entered a new habitat.



a (i) Which of the four phases, labelled **A**, **B**, **C** and **D**, represents the stationary phase and which the lag phase? [2]

(ii) During which phases will some of this insect population die? [2]

b (i) State **two** factors that could affect the rate of population growth during phase **C**. [2]

(ii) Suggest how these two factors might change. Explain how each change would affect the rate of population growth. [4]

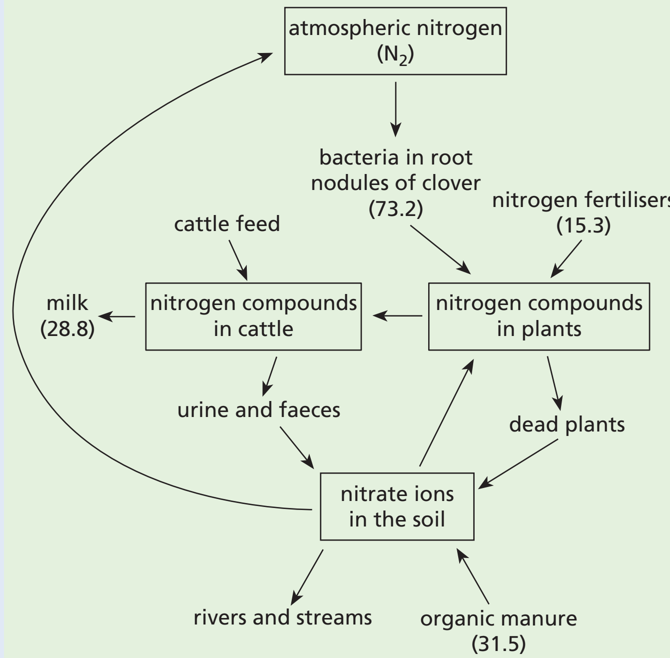
[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 21 Q2 November 2010)

9 An agricultural student investigated nutrient cycles on a farm where cattle are kept for milk. The farmer grows grass and clover as food for the cattle. Clover is a plant that has bacteria in nodules in its roots.

The diagram shows the flow of nitrogen on the farm as discovered by the student. The figures represent the flow of nitrogen in kg per hectare per year.

(A hectare is 10 000 m^2.)



a (i) Name the process in which bacteria convert atmospheric nitrogen into a form that is available to clover plants. [1]

(ii) Name **two** processes that convert nitrogen compounds in dead plants into nitrate ions that can be absorbed by grass. [2]

b The total quantity of nitrogen added to the farmer's fields is 120 kg per hectare per year. Calculate the percentage of this nitrogen that is present in the milk. Show your working. [2]

c State **two** ways in which the nitrogen compounds in the cattle's diet are used by the animals **other than to produce milk**. [2]

d The student found that a large quantity of the nitrogen compounds made available to the farmer's fields was not present in the milk or in the cattle. Use the information in the diagram to suggest what is likely to happen to the nitrogen compounds that are eaten by the cattle, but are not present in compounds in the milk or in their bodies. [5]

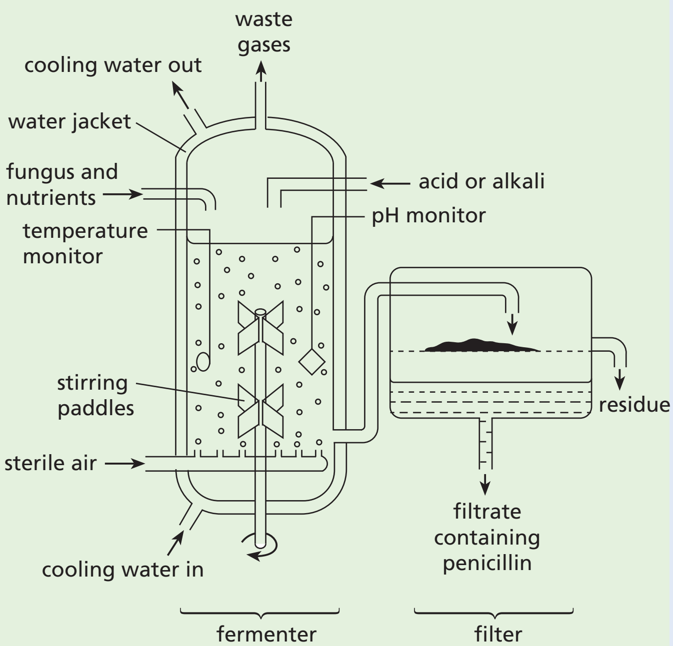
e The carbon dioxide concentration in the atmosphere has increased significantly over the past 150 years. Explain why this has happened. [2]

[Total: 14]

(Cambridge IGCSE Biology 0610 Paper 31 Q6 June 2009)

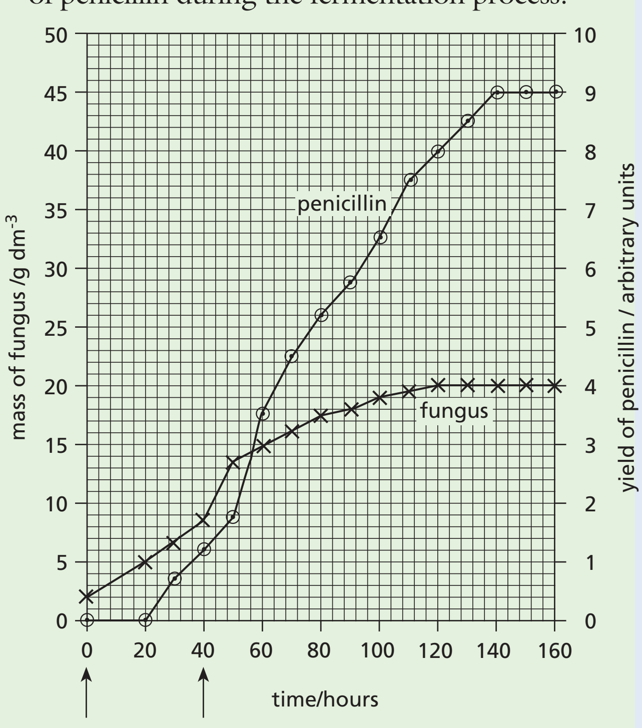
Biotechnology and genetic engineering

1 Penicillin is an antibiotic produced by the fungus *Penicillium chrysogenum*. The diagram shows the process used to produce penicillin.



a Enzymes in the fungus are used to make penicillin. Explain why there is a water jacket around the fermenter and why acids and alkalis are added to the fermenter. [6]

The graph shows the mass of fungus and the yield of penicillin during the fermentation process.



b **(i)** State the time interval over which the fungus grew at the maximum rate. [1]

(ii) As the fungus grows in the fermenter, the nuclei in the fungal hyphae divide. State the type of nuclear division that occurs during the growth of the fungus in the fermenter. [1]

(iii) Explain why the growth of the fungus slows down and stops. [3]

c Penicillin is not needed for the growth of *P. chrysogenum*.

(i) State the evidence from the graph that shows that penicillin is not needed for this growth. [2]

(ii) The people in charge of penicillin production emptied the fermenter at 160 hours. Use the information in the graph to suggest why they did **not** allow the fermentation to continue for longer. [1]

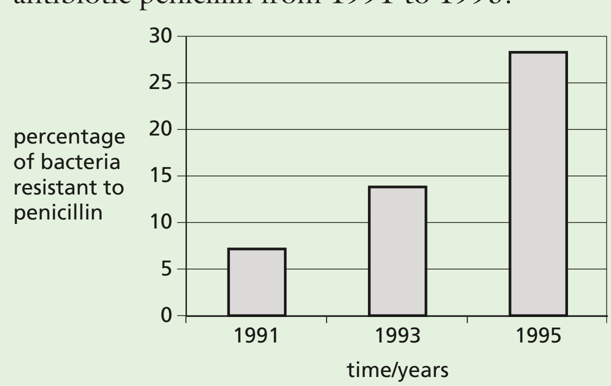
d Downstream processing refers to all the processes that occur to the contents of the fermenter after it is emptied. This involves making penicillin into a form that can be used as medicine. Explain why downstream processing is necessary. [3]

e Explain why antibiotics, such as penicillin, kill bacteria but not viruses. [2]

[Total: 19]

(Cambridge IGCSE Biology 0610 Paper 31 Q4 November 2011)

2 The chart shows the change in percentage of disease-causing bacteria that were resistant to the antibiotic penicillin from 1991 to 1995.



a **(i)** Describe the change in percentage of bacteria resistant to penicillin between 1991 and 1995. [2]

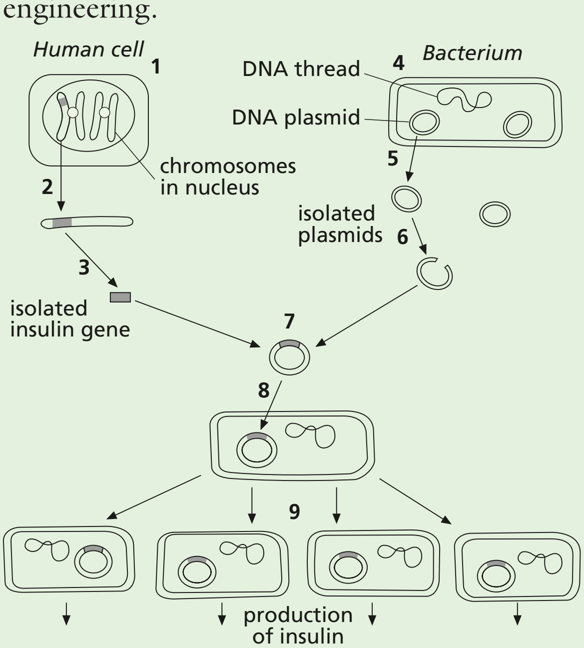
(ii) Explain how a population of antibiotic-resistant bacteria can develop. [4]

b Although bacteria can cause disease, many species are useful in processes such as food production and maintaining soil fertility.

(i) Name **one** type of food produced using bacteria. [1]

(ii) Outline the role of bacteria in maintaining soil fertility. [3]

c Bacteria are also used in genetic engineering. The diagram outlines the process of inserting human insulin genes into bacteria using genetic engineering.



Complete the table below by identifying **one** of the stages shown in the diagram that matches **each** description. [5]

description of stage	number of the stage
the plasmids are removed from the bacterial cell	
a chromosome is removed from a healthy human cell	
plasmids are returned to the bacterial cell	
restriction endonuclease enzyme is used	
bacterial cells are allowed to reproduce in a fermenter	

[Total: 15]

(Cambridge IGCSE Biology 0610 Paper 31 Q4 November 2006)

Human influences on ecosystems

1 Deforestation occurs in many parts of the world.

a State **two** reasons why deforestation is carried out. [2]

b (i) Explain the effects deforestation can have on the **carbon cycle**. [4]

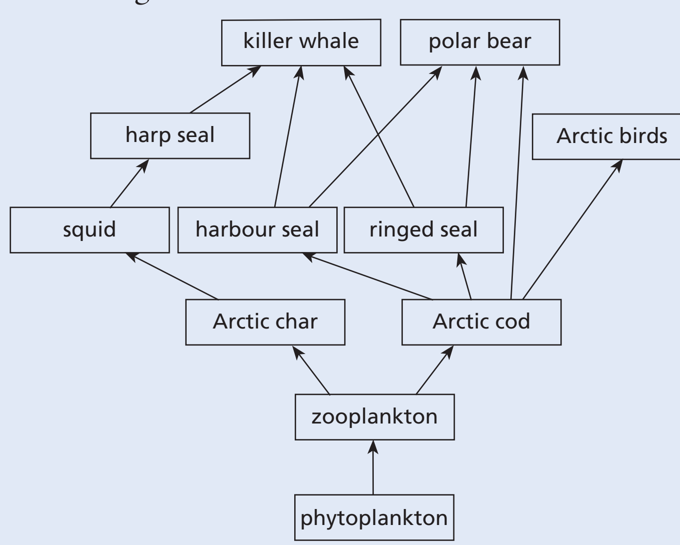
(ii) Describe **two** effects deforestation can have on the soil. [2]

(iii) Forests are important and complex ecosystems. State **two** likely effects of deforestation on the forest ecosystem. [2]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 2 Q2 June 2006)

2 The diagram shows an Arctic food web.



a (i) The phytoplankton are the producers in this food web. Name the process by which phytoplankton build up stores of chemical energy. [1]

(ii) Name a secondary consumer in the food web above. [1]

(iii) Complete the food chain using organisms shown in the food web.

phytoplankton → ____________ → ____________ → ____________ → killer whale [1]

b The polar bear has been listed as an endangered species. Explain what the term *endangered species* means. [2]

c Suggest how the loss of the polar bear from the Arctic ecosystem could affect the population of killer whales. [3]

[Total: 8]

(Cambridge IGCSE Biology 0610 Paper 21 Q5 November 2011)

3 Modern technology can be used to increase the yield of crops.

a The use of chemicals, such as fertilisers, herbicides and pesticides, is one of the developments used.

(i) Name **two** mineral ions commonly included in fertilisers. [1]

(ii) Explain the dangers to the local environment of the overuse of fertilisers on farmland. [4]

(iii) Suggest how the use of herbicides can be of benefit to crop plants. [3]

(iv) Suggest **two** dangers of using pesticides on farmland. [2]

b Artificial selection and genetic engineering can also be used to increase crop yields. Explain the difference between these two techniques. [2]

[Total: 12]

(Cambridge IGCSE Biology 0610 Paper 21 Q9 June 2009)

4 After an accident at a nuclear power plant in 1986, particles containing radioactive strontium were carried like dust in the atmosphere. These landed on grassland in many European countries. When sheep fed on the grass they absorbed the strontium and used it in a similar way to calcium.

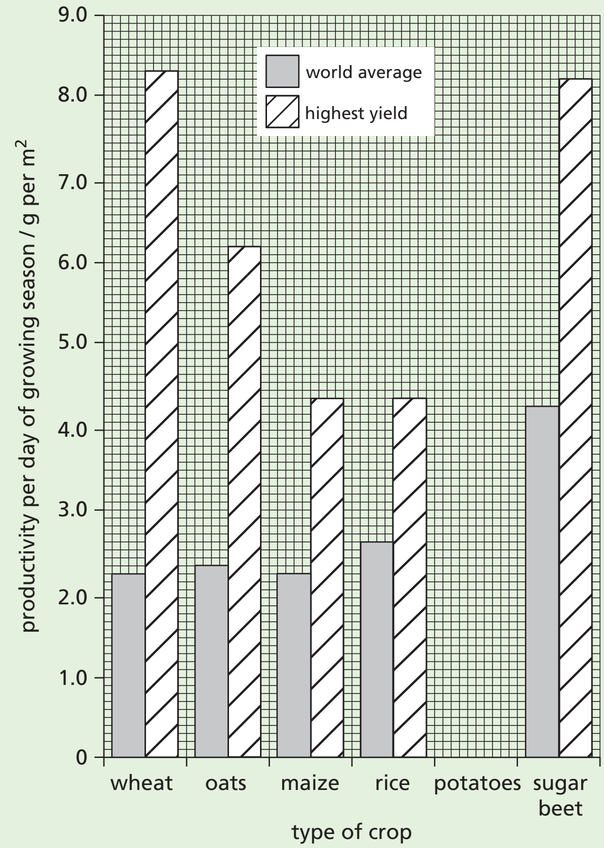
a Explain where in the sheep you might expect the radioactive strontium to become concentrated. [2]

b Suggest the possible effects of the radiation, given off by strontium, on cells in the body of the sheep. [3]

[Total: 5]

(Cambridge IGCSE Biology 0610 Paper 21 Q3 November 2008)

5 The bar graph shows crop productivity for a range of plants but it is incomplete.



a Complete the graph using the following data. [2]

crop	productivity per day of growing season/g per m²	
	world average	highest yield
potatoes	2.6	5.6

b State which crop has

(i) the highest average productivity

(ii) the greatest difference between the average yield and the highest yield. [2]

c Outline how modern technology could be used to increase the productivity of a crop from the average yield to a high yield. [3]

d When the yield is measured, dry mass is always used rather than fresh mass. Suggest why dry mass is a more reliable measurement than fresh mass. [1]

e Maize is often used to feed cows, which are grown to provide meat for humans. Explain why it is more efficient for humans to eat maize rather than meat from cows that have been fed on maize. [3]

f **(i)** Complete the equation for photosynthesis.

$$6CO_2 + 6H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + \underline{\qquad\qquad}$$ [1]

(ii) Describe how leaves are adapted to trap light. [2]

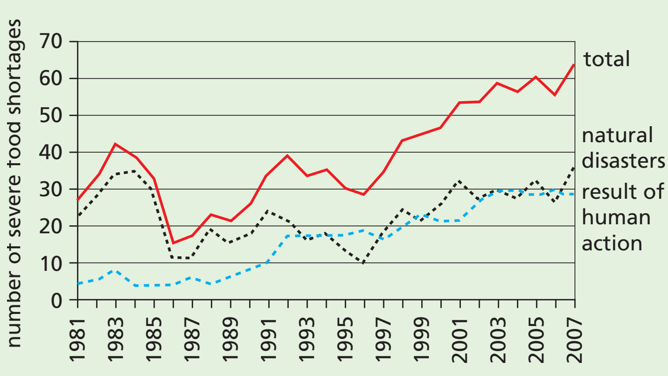
(iii) With reference to water potential, explain how water is absorbed by roots. [3]

(iv) Explain how photosynthesising cells obtain carbon dioxide. [2]

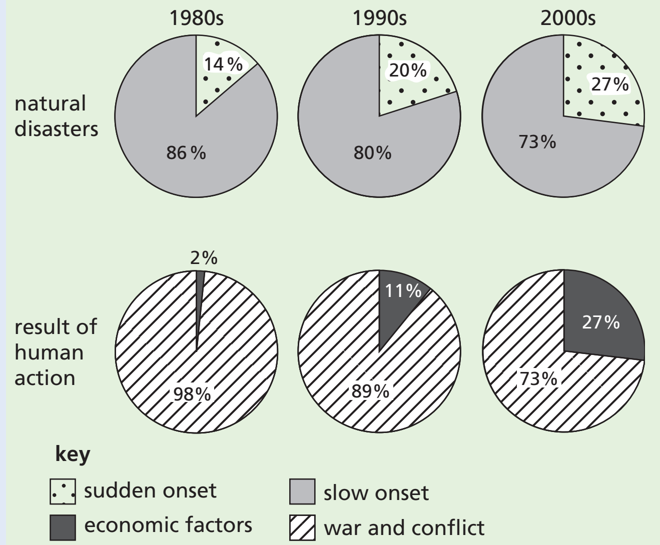
[Total: 19]

(Cambridge IGCSE Biology 0610 Paper 31 Q2 November 2008)

6 The Food and Agriculture Organisation (FAO) collects data on food supplies worldwide. The FAO classifies the causes of severe food shortages as either by natural disasters or as the result of human action. Natural disasters are divided into those that occur suddenly and those that take a long time to develop. Human actions are divided into those that are caused by economic factors and those that are caused by wars and other conflicts. The graph shows the changes in the number of severe food shortages between 1981 and 2007.



The pie charts show the causes of severe food shortages in the 1980s, 1990s and 2000s.



a **(i)** State **two** types of natural disaster that occur suddenly and may lead to severe food shortages. [2]

(ii) State **one** type of natural disaster that may take several years to develop. [1]

b Use the information in the graph and pie charts to describe the changes in food shortages between 1981 and 2007. [5]

c Explain how the increase in the human population may contribute to severe food shortages. [3]

The quality and quantity of food available worldwide has been improved by artificial selection (selective breeding) and genetic engineering.

d Use a **named** example to outline how artificial selection is used to improve the quantity or quality of the food. [4]

e Define the term *genetic engineering*. [1]

[Total: 16]

(Cambridge IGCSE Biology 0610 Paper 31 Q6 June 2010)

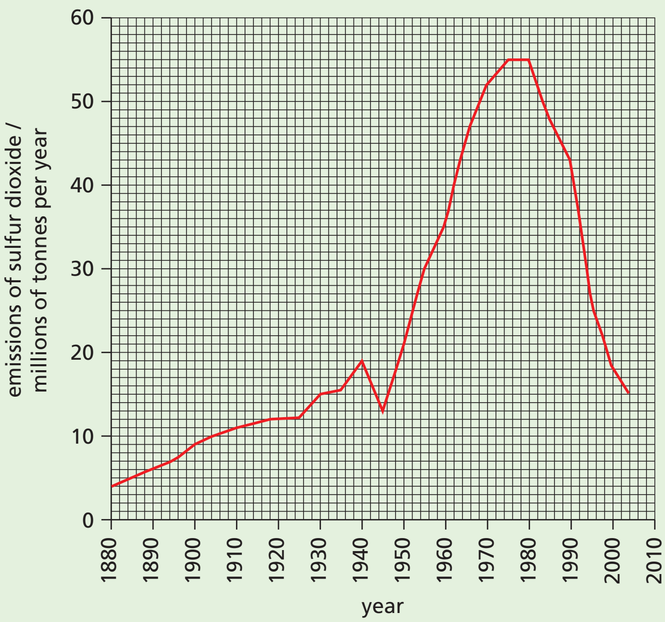
7 The table shows some information about air pollution.

pollutant	source of air pollutant	effect of pollutant on the environment
	combustion of fossil fuels	increased greenhouse effect and global warming
methane		increased greenhouse effect and global warming
sulfur dioxide	combustion of high sulfur fuels	acid rain
nitrogen oxides	fertilisers	acid rain

a Complete the table by writing answers in the spaces. [2]

b Explain how the increased greenhouse effect is thought to lead to global warming. [3]

c The graph shows changes in the emissions of sulfur dioxide in Europe between 1880 and 2004.



(i) Use the information in the graph to describe the changes in the emissions of sulfur dioxide in Europe between 1880 and 2004. [4]

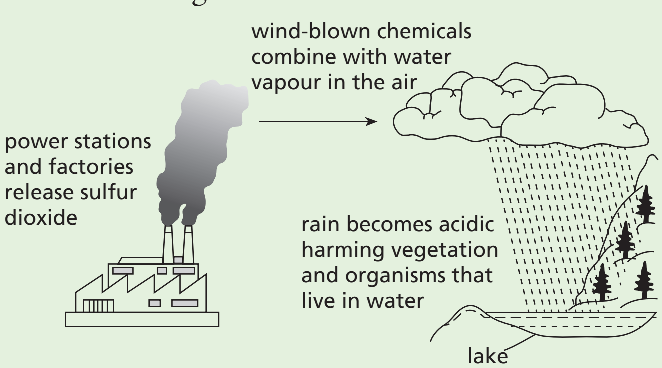
(ii) Describe the effects of acid rain on the environment. [3]

(iii) Outline the methods that have been used to reduce the emissions of sulfur dioxide. [3]

[Total: 15]

(Cambridge IGCSE Biology 0610 Paper 31 Q5 November 2012)

8 Acid rain is a serious environmental problem in some areas of the world. Lakes in Canada, Norway and Scotland are highly acidic as a result of acid rain. The diagram shows a cause of acid rain.



a (i) State **one** cause of acid rain other than that shown in the diagram. [1]

(ii) Describe **two** effects of acid rain on forest ecosystems. [2]

b Describe **two** different ways to reduce pollution so that there is less acid rain. [2]

The chart shows the pH ranges that some animals that live in lakes can tolerate.

animals		pH							
group	examples	7.0	6.5	6.0	5.5	5.0	4.5	4.0	3.5
fish	trout	■	■	■	■	■			
	bass	■	■	■	■				
	perch	■	■	■	■	■	■		
amphibians	frogs	■	■	■	■	■	■	■	
	salamanders	■	■	■	■	■			
molluscs	clams	■	■	■					
	snails	■	■	■					
crustacean	crayfish	■	■	■	■				
insects	mayfly larvae	■	■	■	■				
	blackfly larvae	■	■	■	■	■	■	■	■

c State **one** feature of molluscs that is not a feature of crustaceans. [1]

d Using the information in the chart

(i) name an animal that could be found in a lake with a pH of 4.0 [1]

(ii) name the animals that are most sensitive to a decrease in pH [1]

(iii) suggest why some animals cannot tolerate living in water of pH as low as 4.0. [2]

[Total: 10]

(Cambridge IGCSE Biology 0610 Paper 31 Q4 June 2010)

Answers to numerical questions

2 Organisation and maintenance of the organism

5 b (i) 5 +/– 0.5mm

(ii) 5/800 = 0.00625 or 6.25×10^{-3}

5 Enzymes

1 a (i)

temperature/°C	volume of juice collected/cm^3
10	2
15	11
20	15
25	20
30	26
35	27

3 b (ii) 55 (°C) if point to point curve (+/– half square)

(iii) 24 or 25 (+/– half square)

4 c 0.57

6 Plant nutrition

3 b (i) 1.4

c (i) 6.0–7.0
0–0.6

19 a 1 tonne of wheat per hectare extra

b 1.8 tonnes of wheat per hectare extra

8 Transport in plants

4 b 20.0

9 Transport in animals

2 b (i) calculation x 4 for rate per minute (72, 76, 68) mean calculated: 72

11 Gas exchange in humans

3 d (i) 70

12 Respiration

14 a (i) 8616.2 kJ

(ii) 49.248 kJ

19 Organisms and their environment

1 a (iii) 12 000 kJ

(v) 8000/100 000 × 100 = 8 (%)

9 b 28.8/120 × 100 = 24 (%)

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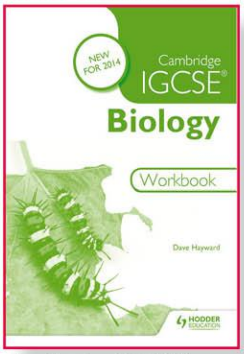

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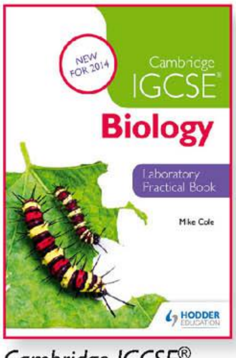

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