UNIVERSITY OF SWAZILAND
FACULTY OF EDUCATION
DEPARTMENT OF CURRICULUM AND TEACHING
FINAL EXAMINATION QUESTION PAPER, DECEMBER 2013

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

INSTRUCTIONS: 1.This examination paper has five (5) questions. Question 1 is compulsory. Then answer any three (3) questions.

2. Each question has a total of 25 points.

3. There is an attachment (IGCSE Biology, McKean, D. G., 2002, pages 26-34; 174-179) for some questions

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Question 1 is compulsory.

1. a) Explain the relationship between hypothesis formulating and hypothesis testing [5]

b) Compare the characteristics of a person who has nominal scientific literacy and one who has functional scientific literacy. [5]

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

d) Explain why individual laboratory activities are preferable to teacher demonstrations. [5]

e) Science teachers often use the following phrase when learners are engaged in laboratory activities
''You'd better finish your work because I will collect your notebooks at the end of the period''.
i) What is the likely classroom environment that would prompt this kind of reaction from the teacher? [2]
ii) Briefly explain the effect this is likely to have on the learners. [3]

Choose any 3 questions below.

2. a) Scientific knowledge, as a product of scientific inquiry, should meet the requirements of description, explanation, prediction and understanding. Explain what is entailed in any **two** of these requirements, giving specific examples. [10]

b) Peter Medawar, Karl Popper and Thomas Kuhn have distinct views on what the criterion of demarcation is for scientific theories and, therefore, scientific knowledge. Discuss their respective views [15]

3. a) In Swaziland science teachers very frequently use demonstration to illustrate scientific phenomena while simultaneously developing inquiry skills in the learners. Explain what the use of the following types of demonstrations entails:
Inductive [4 ½]
Deductive [3 ½]
Experimental [2]

b) The learning cycle or 5E instructional model (engagement, exploration, explanation, elaboration and evaluation) can be used to actively engage learners in knowledge construction that results in the desired conceptual change. Select a topic(s) from the attachment *how substances get in and out of cells,* and illustrate how you would use this model to foster conceptual change in the learners. [15]

4. a) The national science education standards for assessment advocate for *fair* and *accurate* assessment of learner achievement. Provide and explain the forms of assessment that would meet the criteria of fairness and accuracy for achievement in biology. [15]

b) Explain the significance of formative assessment in science. **[10]**

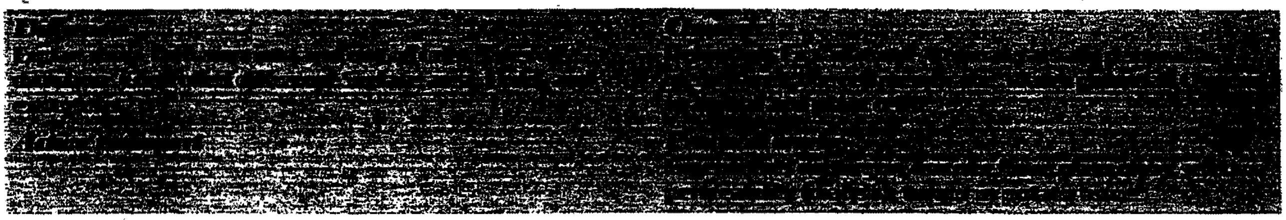
5. Questioning, as a teaching strategy, is advantageous because it allows for inquiry and hence can be used in scientific investigations and discussion. You may refer to the attached topic *personal health* to answer the following questions:

a) Select a section(s) and formulate two divergent questions that demand the use of critical thinking. **[5]**

b) If you were to teach a lesson on the selected section(s), explain how the lesson could be taught using discussion method, ensuring that all learners actively participate in the discussion. **[15]**

c) Write 2 objectives in the **affective** domain that you would wish your learners to attain from the above discussion. **[5]**

4 How substances get in and out of cells



Cells need food materials which they can oxidize for energy or use to build up their cell structures. They also need salts and water which play a part in chemical reactions in the cell. Finally, they need to get rid of substances such as carbon dioxide, which, if they accumulated in the cell, would upset some of the chemical reactions and even poison the cell.

Substances may pass through the cell membrane either passively by diffusion, or actively by some form of active transport.

Diffusion

The molecules of a gas such as oxygen are moving about all the time. So are the molecules of a liquid, or a substance such as sugar dissolved in water. As a result of this movement, the molecules spread themselves out evenly to fill all the available space (Figure 4.1).

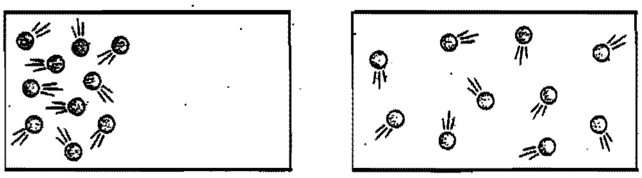


Figure 4.1 Diffusion

This process is called **diffusion**. One effect of diffusion is that the molecules of a gas, a liquid or a dissolved substance will move from a region where there are a lot of them (i.e. concentrated) to regions where there are few of them (i.e. less concentrated) until the concentration everywhere is the same. Figure 4.2a is a diagram of a cell with a high concentration of molecules (e.g. oxygen) outside and a low concentration inside. The effect of this difference in concentration is to make the molecules diffuse into the cell until the concentration inside and outside is the same (Figure 4.2b).

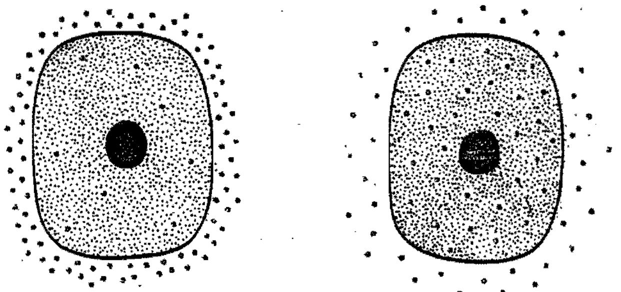


Figure 4.2 Molecules entering a cell by diffusion

Whether this will happen or not depends on whether the cell membrane will let the molecules through. Small molecules such as water (H_2O), carbon dioxide (CO_2) and oxygen (O_2) can pass through the cell membrane fairly easily. So diffusion tends to equalize the concentration of these molecules inside and outside the cell all the time.

When a cell uses up oxygen for its aerobic respiration, the concentration of oxygen inside the cell falls and so oxygen molecules diffuse into the cell until the concentration is raised again. During tissue respiration, carbon dioxide is produced and so its concentration inside the cell goes up. Once again diffusion takes place, but this time the molecules move out of the cell. In this way, diffusion can explain how a cell takes in its oxygen and gets rid of its carbon dioxide.

Rates of diffusion

The speed with which a substance diffuses through a cell wall or cell membrane will depend on temperature, pressure and many other conditions including (1) the distance it has to diffuse, (2) its concentration inside and outside the cell and (3) the size of its molecules or ions.

- Cell membranes are all about the same thickness (about 0.007 μm) but plant cell walls vary in their thickness and permeability. Generally speaking, the thicker the wall, the slower is the rate of diffusion.

• The bigger the difference in concentration of a substance on either side of a membrane, the faster it will tend to diffuse. The difference is called a **concentration gradient** or **diffusion gradient** (Figure 4.3). If a substance on one side of a membrane is steadily removed, the diffusion gradient is maintained. When oxygen molecules enter a red cell they combine with a chemical (haemoglobin) which takes them out of solution. Thus the concentration of free oxygen molecules inside the cell is kept very low and the diffusion gradient for oxygen is maintained.

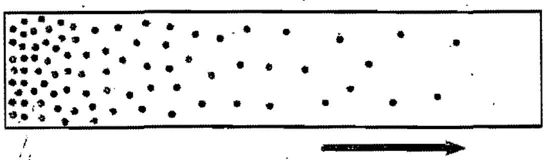


Figure 4.3 Diffusion gradient

• In general, the larger the molecules or ions, the slower they diffuse. However, many ions and molecules in solution attract water molecules around them (see p. 29) and so their effective size is greatly increased. It may not be possible to predict the rate of diffusion from the molecular size alone.

Controlled diffusion

Although for any one substance, the rate of diffusion through a cell membrane depends partly on the concentration gradient, the rate is often faster or slower than expected. Water diffuses more slowly and amino acids diffuse more rapidly through a membrane than might be expected. In some cases this is thought to happen because the ions or molecules can pass through the membrane only by means of special pores. These pores may be few in number or they may be open or closed in different conditions.

In other cases, the movement of a substance may be speeded up by an enzyme working in the cell membrane. So it seems that 'simple passive' diffusion, even of water molecules, may not be so simple or so passive after all, where cell membranes are concerned.

When a molecule gets inside a cell there are a great many structures and processes which may move it from where it enters to where it is needed. Simple diffusion is unlikely to play a very significant part in this movement.

Surface area

If 100 molecules diffuse through 1 mm^2 of a membrane in 1 minute, it is reasonable to suppose that an area of 2 mm^2 will allow twice as many through in the same time. Thus the rate of diffusion into a cell will depend on the cell's surface area. The greater the surface area, the faster is the total diffusion. Cells which are involved in rapid absorption, e.g. in the kidney or the intestine, often have their 'free' surface membrane formed into

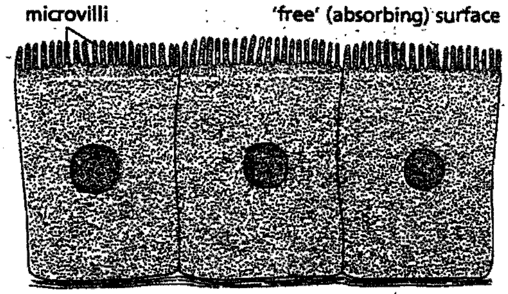


Figure 4.4 Microvilli

Figure 4.5 Surface area. The cells have the same volume but (a) has a much greater surface area

hundreds of tiny projections called **microvilli** (Figure 4.4) which increase the absorbing surface.

The shape of a cell will also affect the surface area. For example, the cell in Figure 4.5a has a greater surface area than that in Figure 4.5b, even though they each have the same volume.

Endo- and exocytosis

Some cells can take in (**endocytosis**) or expel (**exocytosis**) solid particles or drops of fluid through the cell membrane. Endocytosis occurs in single-celled 'animals' such as *Paramecium* (p. 268) when they feed, or in certain white blood cells (phagocytes, p. 108) when they engulf bacteria, a process called **phagocytosis** (Figure 4.6). Exocytosis takes place in the cells of some glands. A secretion, e.g. a digestive enzyme, forms vacuoles or granules in the cytoplasm and these are expelled through the cell membrane to do their work outside the cell (Figure 4.7).

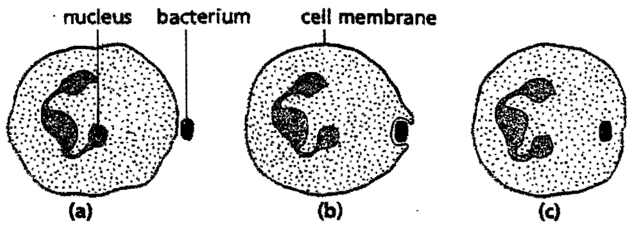


Figure 4.6 Endocytosis (phagocytosis) in a white blood cell

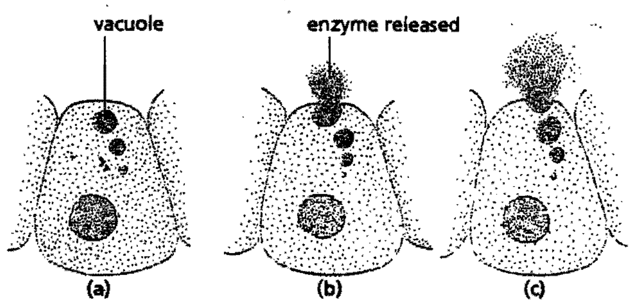


Figure 4.7 Exocytosis in a gland cell

Active transport

If diffusion were the only method by which a cell could take in substances, it would have no control over what went in or out. Anything that was more concentrated outside would diffuse into the cell whether it was harmful or not. Substances which the cell needed would diffuse out as soon as their concentration inside rose above that outside the cell. The cell membrane, however, has a great deal of control over the substances which enter and leave the cell.

In some cases, substances are taken into or expelled from the cell against the concentration gradient. For example, sodium ions may continue to pass out of a cell even though the concentration outside is greater than inside. The processes by which such reverse concentrations are produced are not fully understood and may be quite different for different substances but are all generally described as **active transport**. The cells lining the small intestine take up glucose by active transport (p. 102).

Anything which interferes with respiration, e.g. lack of oxygen or glucose, prevents active transport taking place (Figure 4.8). Thus it seems that active transport needs a supply of energy from respiration.

In some cases, a combination of active transport and controlled diffusion seems to occur. For example, sodium ions are thought to get into a cell by diffusion through special pores in the membrane and are expelled by a form of active transport. The reversed diffusion gradient for sodium ions created in this way is very important in the conduction of nerve impulses in nerve cells.

Plants need to absorb mineral salts from the soil, but these salts are in very dilute solution. Active transport enables the cells of the plant roots to take up salts from this dilute solution against the concentration gradient.

Questions

1 Look at [illegible] represents [illegible] enclosing [illegible] cells on [illegible]

2 Look at [illegible]

a [illegible]

b What might [illegible] blood flow were [illegible]

3 List the ways in which a cell [illegible] the flow of substances into [illegible]

4 What is your interpretation of the [illegible] graph in Figure 4.9?

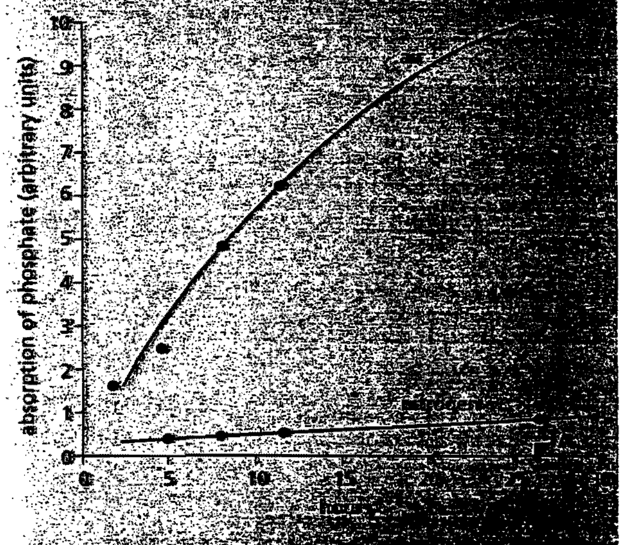


Figure 4.9 Absorption of phosphate [illegible] nitrogen by roots of beech. A represents [illegible] concentration of phosphate in external solution

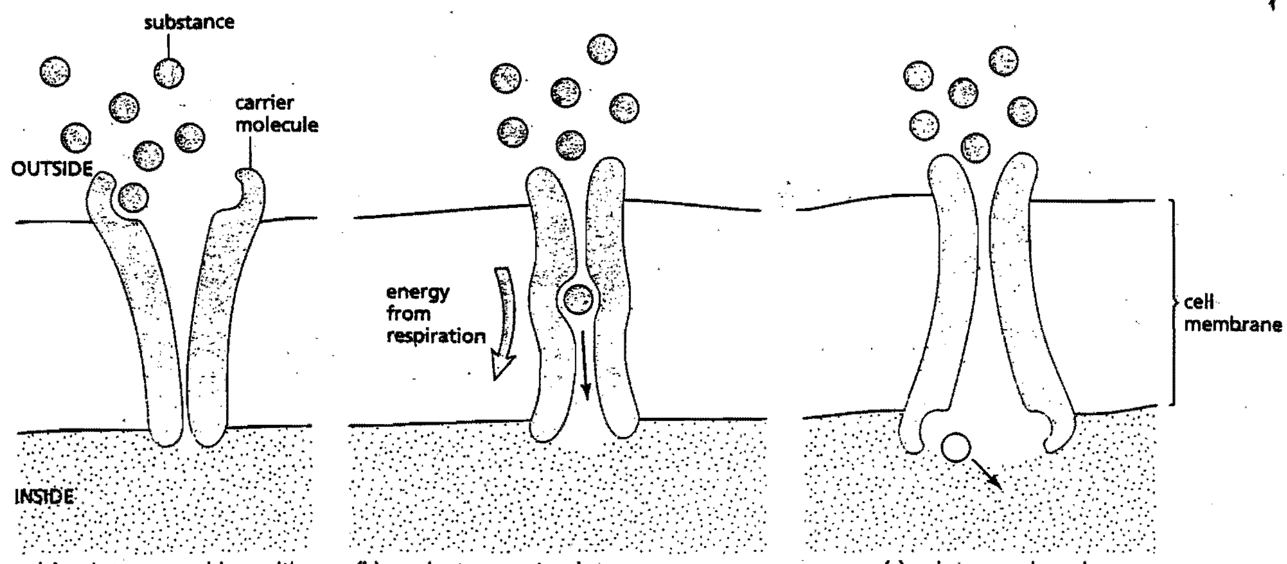


Figure 4.8 Theoretical model to explain active transport

Osmosis

If a dilute solution is separated from a concentrated solution by a **partially permeable** membrane, water diffuses across the membrane from the dilute to the concentrated solution. This is known as **osmosis** (Figure 4.10).

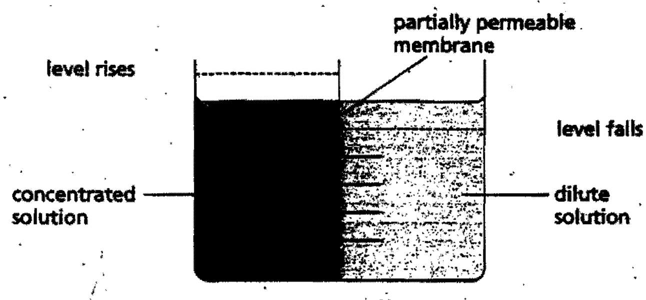


Figure 4.10 Osmosis. Water will diffuse from the dilute to the concentrated solution through the partially permeable membrane. As a result, the liquid level will rise on the left and fall on the right

A partially permeable membrane is porous but allows water to pass through it more rapidly than dissolved substances.

Since a dilute solution contains, in effect, more water molecules than a concentrated solution, there is a diffusion gradient which favours the passage of water from the dilute to the concentrated solution.

In living cells, the cell membrane is partially permeable and the cytoplasm and vacuole (in plant cells) contain dissolved substances. As a consequence, water tends to diffuse into cells by osmosis if they are surrounded by a weak solution, e.g. fresh water. If the cells are surrounded by a stronger solution, e.g. sea water, the cells may lose water by osmosis.

These effects are described more fully on p.30.

Explanation of osmosis

When a substance such as sugar dissolves in water, the sugar molecules attract some of the water molecules and stop them moving freely. This, in effect, reduces the concentration of water molecules. In Figure 4.11 the sugar molecules on the right have 'captured' half the water molecules. There are more free water molecules on the left of the membrane than on the right, so water will diffuse more rapidly from left to right across the membrane than from right to left.

The partially permeable membrane does not act like a sieve, in this case. The sugar molecules can diffuse from right to left but, because they are bigger and surrounded by a cloud of water molecules, they diffuse more slowly than the water (Figure 4.12).

Artificial partially permeable membranes are made from cellulose acetate in sheets or tubes and used for **dialysis** (p.34) rather than for osmosis. The pore size can be adjusted during manufacture so that large molecules cannot get through at all.

The **cell membrane** behaves like a partially permeable membrane. The partial permeability may depend on pores in the cell membrane but the processes involved are far more complicated than in an artificial membrane and depend on the structure of the membrane and on living processes in the cytoplasm (see p.27). The cell membrane contains lipids and proteins. Anything which denatures proteins, e.g. heat, also destroys the structure and the partially permeable properties of a cell membrane. If this happens, the cell will die as essential substances diffuse out of the cell and harmful chemicals diffuse in.

Water potential

The **water potential** of a solution is a measure of whether it is likely to lose or gain water molecules from another solution. A dilute solution, with its high proportion of free water molecules, is said to have a higher water potential than a concentrated solution, because water will flow from the dilute to the concentrated solution (from a high potential to a low potential). Pure water has the highest possible water potential because water molecules will flow from it to any other aqueous solution, no matter how dilute.

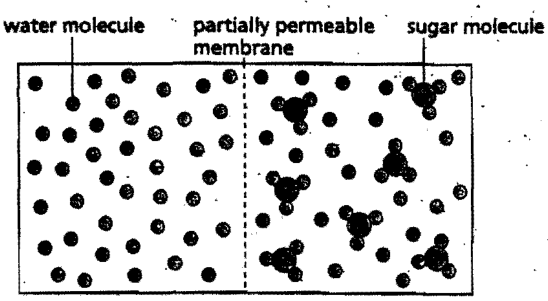


Figure 4.11 The diffusion gradient for water. There are more free water molecules on the left, so more will diffuse from left to right than in the other direction. Sugar molecules will diffuse more slowly from right to left

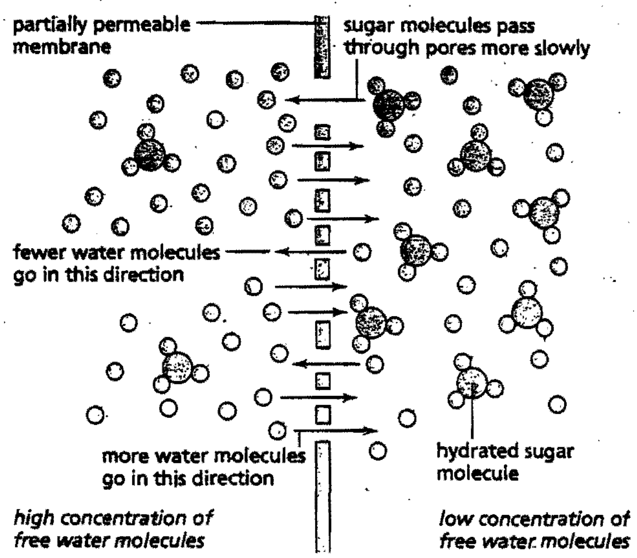
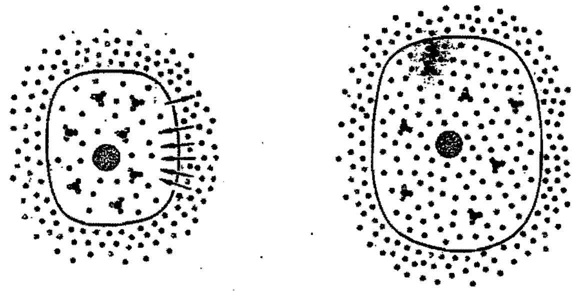


Figure 4.12 The diffusion theory of osmosis



(a) There is a higher concentration of free water molecules outside the cell than inside, so water diffuses into the cell.

(b) The extra water makes the cell swell up.

(Note that molecules are really far too small to be seen at this magnification.)

Figure 4.13 Osmosis in an animal cell

Animal cells

In Figure 4.13 an animal cell is shown very simply. The coloured circles represent molecules in the cytoplasm. They may be sugar, salt or protein molecules. The grey circles represent water molecules.

The cell is shown surrounded by pure water. Nothing is dissolved in the water; it has 100 per cent concentration of water molecules. So the concentration of free water molecules outside the cell is greater than that inside and, therefore, water will diffuse into the cell by osmosis.

The membrane allows water to go through either way. So in our example, water can move into or out of the cell.

The cell membrane is partially permeable to most of the substances dissolved in the cytoplasm. So although the concentration of these substances inside may be high, they cannot diffuse freely out of the cell.

The water molecules move into and out of the cell, but because there are more of them on the outside, they will move in faster than they move out. The liquid outside the cell does not have to be 100 per cent pure water. As long as the concentration of water outside is higher than that inside, water will diffuse in by osmosis.

Water entering the cell will make it swell up, and unless the extra water is expelled in some way the cell will burst.

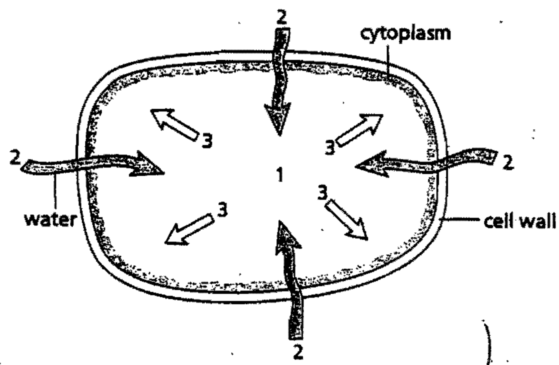
Conversely, if the cells are surrounded by a solution which is more concentrated than the cytoplasm, water will pass out of the cell by osmosis and the cell will shrink. Excessive uptake or loss of water by osmosis may damage cells.

For this reason, it is very important that the cells in an animal's body are surrounded by a liquid which has the same concentration as the liquid inside the cells. The outside liquid is called 'tissue fluid' (see p. 113) and its concentration depends on the concentration of the blood. In vertebrate animals the blood's concentration is monitored by the brain and adjusted by the kidneys, as described on p. 133.

By keeping the blood concentration within narrow limits, the concentration of tissue fluid remains more or less constant (see pp. 116 and 135) and the cells are not bloated by taking in too much water, or dehydrated by losing too much.

Plant cells

The cytoplasm of a plant cell and the cell sap in its vacuole contain salts, sugars and proteins which effectively reduce the concentration of free water molecules inside the cell. The cell wall is freely permeable to water and dissolved substances but the cell membrane of the cytoplasm is partially permeable. If a plant cell is surrounded by water or a solution more dilute than its contents, water will pass into the vacuole by osmosis. The vacuole will expand and press outwards on the cytoplasm and cell wall. The cell wall of a mature plant cell cannot be stretched, so there comes a time when the inflow of water is resisted by the unstretchable cell wall (Figure 4.14).



1 since there is effectively a lower concentration of water in the cell sap
2 water diffuses into the vacuole
3 and makes it push out against the cell wall

Figure 4.14 Osmosis in a plant cell

This has a similar effect to inflating a soft bicycle tyre. The tyre represents the firm cell wall, the floppy inner tube is like the cytoplasm and the air inside corresponds to the vacuole. If enough air is pumped in, it pushes the inner tube against the tyre and makes the tyre hard. A plant cell with the vacuole pushing out on the cell wall is said to be **turgid** and the vacuole is exerting **turgor pressure** on the cell wall.

If all the cells in a leaf and stem are turgid, the stem will be firm and upright and the leaves held out straight. If the vacuoles lose water for any reason, the cells will lose their turgor and become **flaccid** (Experiment 3, p. 32). A leaf with flaccid cells will be limp and the stem will droop. A plant which loses water to this extent is said to be 'wilting' (Figure 4.15).

Figure 4.15 Wilting

Questions

1 A 10 per cent solution of copper [illegible] separated by a partially permeable membrane [illegible] 5 per cent solution of copper sulphate. Will [illegible] from the 10 per cent to the 5 per cent solution [illegible] cent to the 10 per cent solution? [illegible]

2 If a fresh beetroot is cut up, the pieces [illegible] and then left for an hour in a beaker [illegible] no red pigment escapes from the cells [illegible] the beetroot is boiled first, the pigment [illegible] the water. Bearing in mind the properties [illegible] membrane, offer an explanation for [illegible]

3 When doing experiments with [illegible] usually bathed in Ringer's solution [illegible] concentration similar to that of blood [illegible] Why do you think this is necessary?

4 Why does a dissolved substance [illegible] 'free' water molecules in a solution? [illegible]

5 When a plant leaf is in daylight, its cells make sugar from carbon dioxide and water (see p. 35). The sugar is at once turned into starch and deposited in plastids. What is the osmotic advantage of doing this? (Sugar is soluble in water; starch is not. See p. 12.)

Practical work

Experiments on osmosis and dialysis

Experiments 1, 2 and 5 use 'Visking' dialysis tubing. It is made from cellulose and is partially permeable, allowing water molecules to diffuse through freely, but restricting the passage of dissolved substances to varying extents. It is used in kidney dialysis machines because it lets the small molecules of harmful waste products (e.g. urea, p. 134) out of the blood but retains the blood cells and large protein molecules.

1 Osmosis and turgor

Take a 20 cm length of dialysis tubing which has been soaked in water and tie a knot tightly at one end. Place 3 cm^3 of a strong sugar solution in the tubing using a plastic syringe (Figure 4.16a) and then knot the open end of the tube (Figure 4.16b). The partly filled tube should be quite floppy (Figure 4.16c). Place the tubing in a test-tube of water for 30–45 minutes. After this time, remove the dialysis tubing from the water and look for any changes in how it looks or feels.

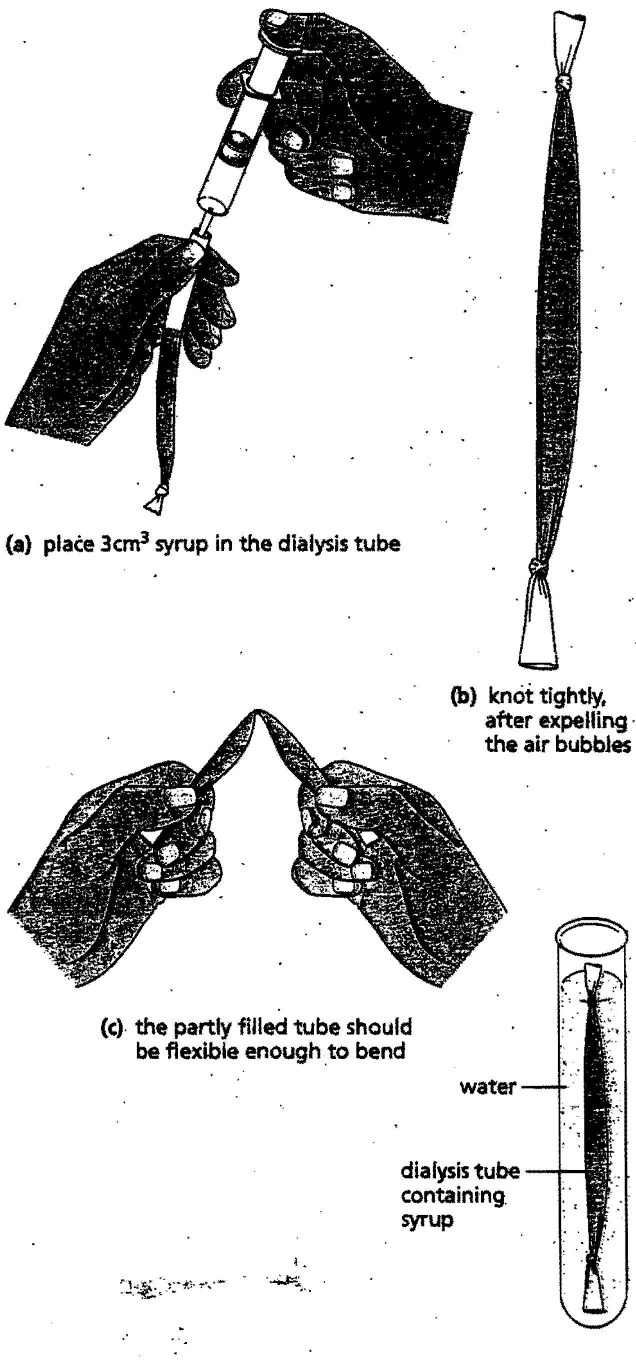


Figure 4.16 Experiment to illustrate turgor in a plant cell

Result The tubing will now be firm, distended by the solution inside.

Interpretation The dialysis tubing is partially permeable and the solution inside has fewer free water molecules than outside. Water has, therefore, diffused in and increased the volume and the pressure of the solution inside.

This is a crude model of what is thought to happen to a plant cell when it becomes turgid. The sugar solution represents the cell sap and the dialysis tubing represents the cell membrane and cell wall combined.

2 Osmosis and water flow

Tie a knot in one end of a piece of soaked dialysis tubing and fill it with sugar solution as in the previous experiment but, this time, add a little coloured dye. Then fit it over the end of a length of capillary tubing and hold it in place with an elastic band. Push the capillary tubing into the dialysis tubing until the sugar solution enters the capillary. Now clamp the capillary tubing so that the dialysis tubing is totally immersed in a beaker of water as shown in Figure 4.17. Watch the level of liquid in the capillary tubing over the next 10 or 15 minutes.

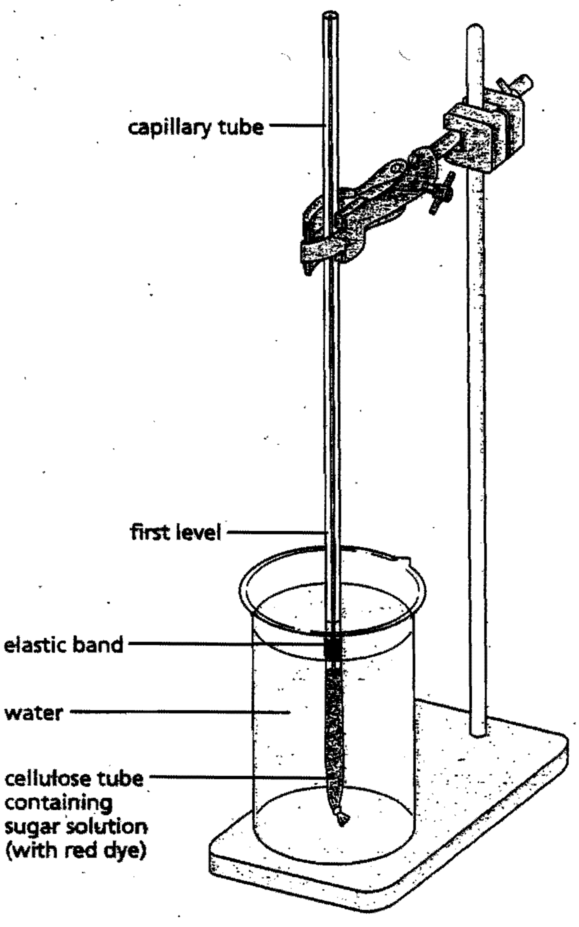


Figure 4.17 Demonstration of osmosis

Result The level of liquid in the capillary tube will be seen to rise.

Interpretation Water must be passing into the sugar solution from the beaker. This is what you would expect when a concentrated solution is separated from water by a partially permeable membrane. The results are similar to those in Experiment 1 but instead of the expanding solution distending the dialysis tube, it escapes up the capillary.

A process similar to this might be partially responsible for moving water from the roots to the stem of a plant.

3 Plasmolysis

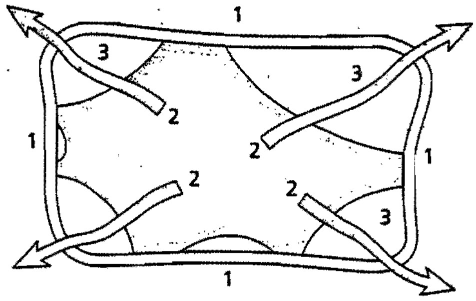
Peel a small piece of epidermis (outer layer of cells) from a red area of a rhubarb stalk (see Figure 1.15a, p. 9). Place the epidermis on a slide with a drop of water and cover with a cover-slip (see Figure 1.15c, p. 9). Place a 30 per cent solution of sugar at one edge of the cover-slip with a pipette and then draw the solution under the cover-slip by placing a piece of blotting-paper on the opposite side (Figure 4.18). As you are doing this, study a small group of cells under the microscope and watch for any changes in their appearance (Figure 4.20).

Figure 4.18 Changing the water for sugar solution

Result The red cell sap will appear to shrink and get darker and pull the cytoplasm away from the cell wall leaving clear spaces. (It will not be possible to see the cytoplasm but its presence can be inferred from the fact that the red cell sap seems to have a distinct outer boundary in those places where it has separated from the cell wall.)

Interpretation The interpretation in terms of osmosis is outlined in Figure 4.19. The cells are said to be **plasmolysed.**

The plasmolysis can be reversed by drawing water under the cover-slip in the same way that you drew the sugar solution under. It may need two or three lots of water to flush out all the sugar. If you watch a group of cells, you should see their vacuoles expanding to fill the cells once again.



1 the solution outside the cell is more concentrated than the cell sap
2 water diffuses out of the vacuole
3 the vacuole shrinks, pulling the cytoplasm away from the cell wall, leaving the cell flaccid

Figure 4.19 Plasmolysis

Rhubarb is used for this experiment because the coloured cell sap shows up. If rhubarb is not available the epidermis from a red onion scale can be used with results similar to those in Figure 4.20.

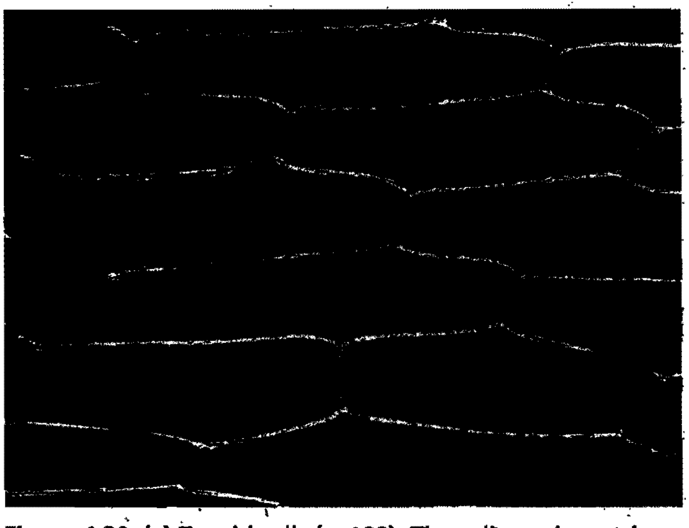
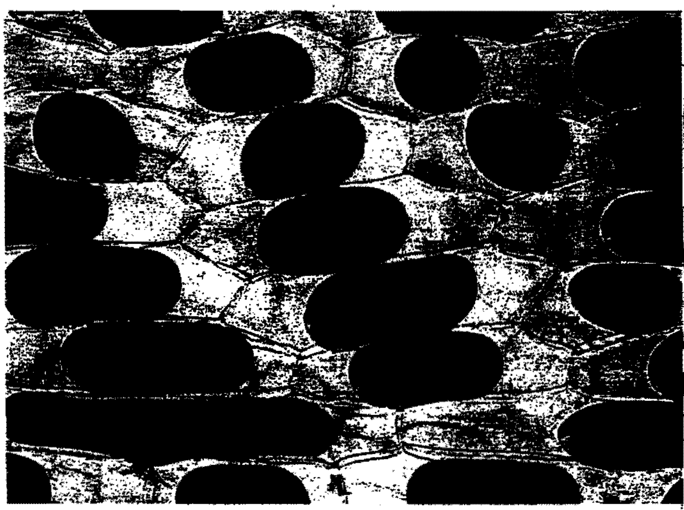


Figure 4.20 **(a)** Turgid cells (× 100). The cells are in a strip of epidermis from a red onion scale. The cytoplasm is pressed against the inside of the cell wall by the vacuole



(b) Plasmolysed cells (× 100). The same cells as they appear after treatment with salt solution. The vacuole has lost water by osmosis, shrunk and pulled the cytoplasm away from the cell wall

4 Turgor in potato tissue

Push a No. 4 or No. 5 cork borer into a large potato. *Caution* Do not hold the potato in your hand but use a board as in Figure 4.21a.

Push the potato tissue out of the cork borer using a pencil as in Figure 4.21b. Prepare a number of potato cylinders in this way and choose the two longest (at least 50 mm). Cut these two accurately to the same length, e.g. 50, 60 or 70 mm. Measure carefully.

Label two test-tubes A and B and place a potato cylinder in each. Cover the potato tissue in tube A with water; cover the tissue in B with a 20 per cent sugar solution. Leave the tubes for a day.

After this time, remove the cylinder from tube A and measure its length. Notice also whether it is firm or flabby. Repeat this for the potato in tube B, but rinse it in water before measuring it.

Result The cylinder from tube A should have gained a millimetre or two and feel firm. The cylinder from tube B should be a millimetre or two shorter and feel flabby.

Interpretation If the potato cells were not fully turgid at the beginning of the experiment, they would take up water by osmosis (tube A), and cause an increase in length.

In tube B, the sugar solution is stronger than the cell sap of the potato cells, so these cells will lose water by osmosis. The cells will lose their turgor and the potato cylinder will become flabby and shorter.

An alternative to measuring the potato cores is to weigh them before and after the 24 hours' immersion in water or sugar solution. The core in tube A should gain weight and that in tube B should lose weight. It is important to blot the cores dry with a paper towel before each weighing.

Whichever method is used, it is a good idea to pool the results of the whole class since the changes may be quite small. A gain in length of 1 or 2 mm might be due to an error in measurement, but if most of the class record an increase in length, then experimental error is unlikely to be the cause.

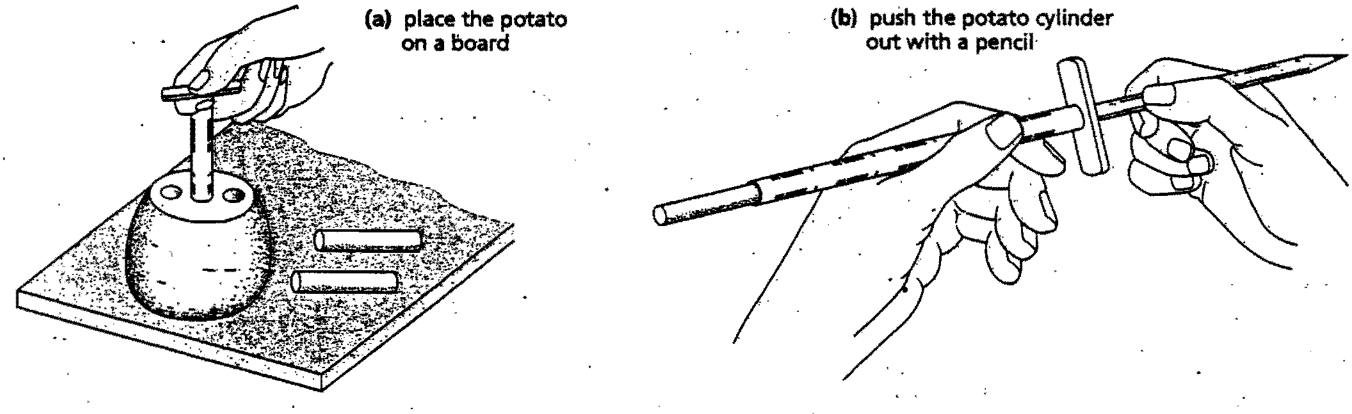


Figure 4.21 Obtaining cylinders of potato tissue

5 Partial permeability (dialysis)

Take a 15 cm length of dialysis tubing which has been soaked in water and tie a knot tightly at one end. Use a dropping pipette to partly fill the tubing with 1 per cent starch solution. Put the tubing in a test-tube and hold it in place with an elastic band as shown in Figure 4.22. Rinse the tubing and test-tube under the tap to remove all traces of starch solution from the outside of the dialysis tube.

Fill the test-tube with water and add a few drops of iodine solution to colour the water yellow. Leave for 10–15 minutes.

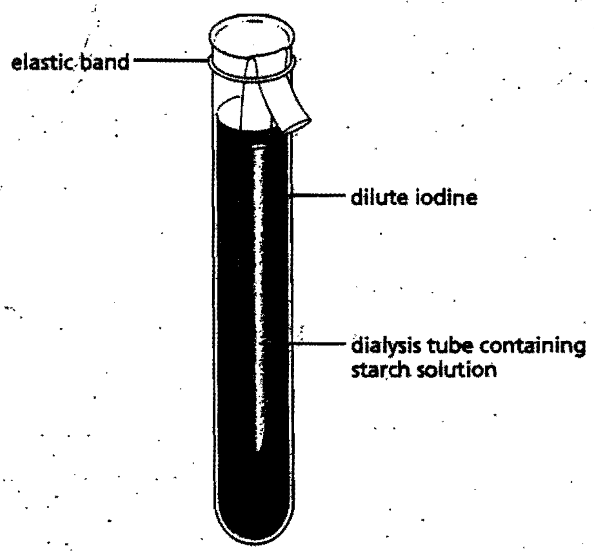


Figure 4.22 Dialysis

Result The starch inside the dialysis tubing goes blue but the iodine outside stays yellow.

Interpretation The blue colour is characteristic of the reaction which takes place between starch and iodine, and is used as a test for starch (see p. 95). The results show that iodine molecules have passed through the dialysis tubing into the starch but the starch molecules have not moved out into the iodine. This is what we would expect if the dialysis tubing were partially permeable on the basis of its pore size. Starch molecules are very large (see p. 12) and probably cannot get through the pores. Iodine molecules are much smaller and can, therefore, get through.

Note This experiment illustrates the process of dialysis rather than osmosis. The movement of water is not necessarily involved and the pore size of the membrane makes it genuinely partially permeable with respect to iodine and starch.

Questions

1 In Experiment 2 (Figure 4.17), [illegible] happen
   a if a much stronger sugar solution [illegible] cellulose tube?
   b if the beaker contained a [illegible] instead of water?
   c if the sugar solution [illegible] was in the cellulose tube?
2 In Experiment 1 (Figure 4.16), [illegible] cellulose tube filled with sugar [illegible] water for several hours?
3 In Experiment 3, Figure 4.19 [illegible] shrinks. Give a brief explanation [illegible] again when the cell is surrounded [illegible]
4 An alternative interpretation of the [illegible] Experiment 5 might be that the dialysis [illegible] molecules (of any size) to pass in but not [illegible] an experiment to test this possibility and [illegible] results you would expect
   a if it were correct and
   b if it were false.
5 In Experiment 2 on p. 32, the column of liquid accumulating in the capillary tube exerts [illegible] increasing pressure on the solution in the dialysis tube. Bearing this in mind and assuming a very long capillary, at what stage would you expect the net flow of water from the beaker into the dialysis tubing to cease? [illegible]

Checklist

- Diffusion is the result of molecules of liquid, gas or dissolved solid moving about.
- The molecules of a substance diffuse from a region where they are very concentrated to a region where they are less concentrated.
- Substances may enter cells by simple diffusion, controlled diffusion, active transport or endocytosis.
- Osmosis is the diffusion of water through a partially permeable membrane.
- Water diffuses from a dilute solution of salt or sugar to a concentrated solution because the concentrated solution contains fewer free water molecules.
- Cell membranes are partially permeable and cytoplasm and cell sap contain many substances in solution.
- Cells take up water from dilute solutions but lose water to concentrated solutions because of osmosis.
- Osmosis maintains turgor in plant cells.

20 Personal health

Diet
Dental health
Dental decay. Gum disease. Fluoridation of water supplies.
Smoking
Exercise
Mood-influencing drugs
Tolerance and dependence. Stimulants; depressants.
Alcohol. Hallucinogens. Narcotics.
Solvent misuse

Health is not merely the absence of disease but a state of physical and mental well-being. However, you are not usually aware of your state of health until you are unwell. Therefore you may need to make a conscious effort to maintain good health.

The general rules for health are:

Do eat a balanced diet
take regular exercise
develop a positive attitude to life

Don't smoke
drink too much
misuse drugs.

If you feel this recipe for health is 'boring', ask yourself whether being overweight, having bronchitis, craving drugs and alcohol, and looking forward to premature heart failure are likely to make you happy and content.

You may know middle-aged or elderly people who claim to have smoked, got drunk, over-eaten and taken no exercise all their lives, and still remain healthy. You will also have heard of fit people who exercise regularly and do not smoke but die suddenly from a heart attack.

These stories prove nothing. We inherit part of our 'constitution' from our parents. So some people are more able than others to resist disease and to ill-use their bodies. You can do nothing about your genes, but you can do a lot to make the best of the constitution you have inherited.

You can find physiological reasons for some of the 'dos and don'ts' listed in the preceding chapters (for diet see pp. 90–1, smoking pp. 127–9 and exercise p. 156). This chapter will refer to them only briefly. In some cases, such as smoking and drug abuse, there is overwhelming evidence to support the advice. In others, such as diet and exercise, the evidence is less strong, but the advice given represents most expert opinion.

Diet

To remain healthy, you must eat enough food to meet all your energy requirements. It must contain protein and fat to make new cells. You also need vitamins and salts (see pp. 87–9).

A healthy diet should contain only a little salt and refined sugar (if any) and a low proportion of fat. The diet also needs to include plenty of vegetable fibre (Figure 20.1). A low fat intake may help reduce the chances of arterial and heart disease (p. 120). A high fibre intake probably helps to prevent diseases of the large intestine.

In some people, over-eating can lead to obesity with its attendant problems (such as high blood pressure and diabetes).

A healthy digestive system also depends on regular meals eaten in a relaxed atmosphere. Hasty snacks and irregular heavy meals can lead to digestive disorders.

The health aspects of diet are discussed more fully on pp. 90–2.

Figure 20.1 Some components of a healthy diet

Dental health

Sugary food and the neglect of oral hygiene can lead to toothache, gum disease and, ultimately, the loss of the teeth and the need to wear dentures.

Dental decay (dental caries)

Decay begins when small holes (cavities) appear in the enamel. The cavities are caused by bacteria on the tooth surface. The bacteria produce acids which dissolve the calcium salts in the tooth enamel. The enamel and dentine are dissolved away in patches, forming cavities. The cavities reduce the distance between the outside of the tooth and the nerve endings. The acids produced by the bacteria irritate the nerve endings and cause toothache. If the cavity is not cleaned and filled by a dentist, the bacteria will get into the pulp cavity and cause a painful abscess at the root. Often, the only way to treat this is to have the tooth pulled out.

Although some people's teeth are more resistant to decay than others, it seems that it is the presence of refined sugar (sucrose) that contributes to decay.

Western diets contain a good deal of refined sugar and children suck sweets between one meal and the next. The high level of dental decay in Western society is thought to be caused mainly by keeping sugar in the mouth for long periods of time.

The graph in Figure 20.2a shows how the pH in the mouth falls (i.e. becomes more acid) when a single sweet is sucked. The pH below which the enamel is attacked is called the **critical pH** (between 5.5 and 6). In this case, the enamel is under acid attack for about 10 minutes.

The graph in Figure 20.2b shows the effect of sucking sweets at the rate of four an hour. In this case the teeth are exposed to acid attack almost continually.

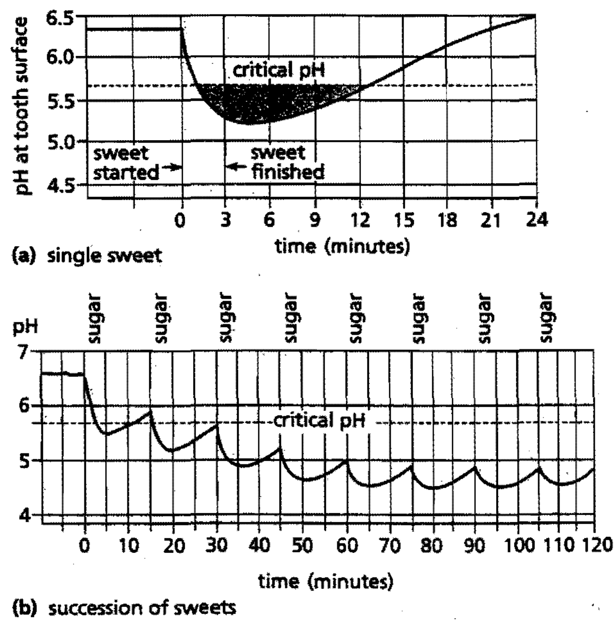


Figure 20.2 pH in the mouth when sweets are sucked

The best way to prevent tooth decay, therefore, is to avoid eating sugar at frequent intervals either in the form of sweets or in sweet drinks such as orange squash or cola drinks.

It is advisable also to visit the dentist every 6 months or so for a 'check-up' so that any caries or gum disease can be treated at an early stage.

Brushing the teeth is very important in the prevention of gum disease. It may not be so effective in preventing caries although the use of fluoride toothpaste does help to reduce the bacterial population on the teeth and to increase their resistance to decay (see below).

Gum disease (periodontal disease)

There is usually a layer of saliva and mucus over the teeth. This layer contains bacteria which live on the food residues in the mouth, building up a coating on the teeth, called **plaque**. If the plaque is not removed, mineral salts of calcium and magnesium are deposited on it, forming a hard layer of 'tartar' or **calculus**. If the bacterial plaque which forms on teeth is not removed regularly, it spreads down the tooth into the narrow gap between the gum and enamel. Here it causes inflammation, called **gingivitis**, which leads to redness and bleeding of the gums and to bad breath. It also causes the gums to recede and expose the cement. If gingivitis is not treated, it progresses to **periodontitis**; the fibres holding the tooth in the jaw are destroyed, so the tooth becomes loose and falls out or has to be pulled out.

There is evidence that cleaning the teeth does help to prevent gum disease. It is best to clean the teeth about twice a day using a toothbrush. No one method of cleaning has proved to be any better than any other but the cleaning should attempt to remove all the plaque from the narrow crevice between the gums and the teeth.

Drawing a waxed thread ('dental floss') between the teeth helps to remove plaque in these regions.

Fluoridation of water supplies

It has been known for many years that the presence of fluoride ions in drinking water reduces the incidence of dental decay by 30 per cent or more, particularly in children. The fluoride salts, which reach the teeth in the blood supply, are built into the enamel of the teeth and increase resistance to bacterial attack. Fluoride reaching the surface of the teeth has a similar effect and also reduces the bacterial population in the plaque.

To benefit from this effect, local authorities are permitted to add sodium fluoride to drinking water at a concentration of about 1 part per million (1 ppm). In regions where this has been done there has been a reducion in dental caries of up to 50 per cent. In the USA, 60 per cent of the population now receives fluoridated water. In Britain the figure is about 10 per cent.

After 50 years of intensive studies, there is no scientific evidence that fluoride at 1 ppm is harmful. Claims of increases in bone cancer, or bone fragility and many other hazards, have been shown to be unfounded. The one disadvantage is the small possibility of dental fluorosis in which the teeth develop pearly white patches. This occurs when the fluoride intake exceeds the 1 ppm level. For example, it may happen if children swallow fluoride toothpaste in regions where the water already has adequate fluoride. In the few cases where fluorosis occurs, the condition can often be observed only by expert dental inspection.

Opponents of fluoridation feel that it is a form of 'mass medication', a health measure forced on the population to achieve medical benefits rather than just making the water safer to drink, as is the case with chlorination (p. 340). They would say that parents should be free to decide whether to supplement their children's fluoride intake by using fluoride toothpaste or fluoride tablets. They would point out also that, by adopting good dietary and dental practices, caries can be reduced without resort to fluoridation

Smoking

There is a long list of diseases associated with smoking, including lung cancer, bronchitis, emphysema, arterial disease, stomach ulcers and bladder cancer. This does not mean that all smokers will develop these diseases. But the chances of their doing so are far higher than they are for non-smokers.

See pp. 127–9 for more detail.

Exercise

Exercise increases stamina, improves flexibility, makes muscles stronger and more efficient, and helps to keep your weight down (Figure 20.3). Exercise may also reduce your chance of a premature coronary heart attack, though the evidence is not clear-cut.

Figure 20.3 Exercise. Regular exercise contributes to good health

Most people agree that exercise makes you 'feel good'. But to enjoy the benefits, you need to take exercise throughout your life.

Exercise is discussed in more detail on p. 156.

[illegible]

Mood-influencing drugs

Any substance used in medicine to help our bodies fight illness or disease is called a **drug**. One group of drugs helps to control pain and ease feelings of distress. These are the mood-influencing drugs.

Sensations of excitement, well-being or depression are the products of our nervous and endocrine systems. The mood-influencing drugs mimic the effects of our hormones or neurotransmitters (p. 165) and produce corresponding states of mind.

If these drugs are used wisely and under medical supervision, they can be very helpful. A person who feels depressed to the point of wanting to commit suicide may be able to lead a normal life with the aid of an antidepressant drug which removes the feeling of depression. However, if drugs are used for trivial reasons, to produce feelings of excitement or calm, they may be extremely dangerous. This is because they can cause **tolerance** and **dependence**.

Tolerance

This means that if the substance is taken over a long period, the dosage has to keep increasing in order to have the same effect. People who take sleeping pills containing barbiturates may need to increase the dose from one to two or three tablets in order to get to sleep. People who drink alcohol in order to relieve anxiety may find that they have to keep drinking more and more before they feel relaxed. If the dosage continues to increase it will become so large that it causes death.

Dependence

This is the term used to describe the condition in which the user cannot do without the substance.

Sometimes a distinction is made between emotional and physical dependence, though the distinction is not always clear. A person with emotional dependence may feel a craving for the substance, may be bad-tempered, anxious or depressed without it, and may commit crimes in order to obtain it. Cigarette smoking is one example of emotional dependence.

Physical dependence involves the same experiences. But there are also physical symptoms called **withdrawal symptoms**, when the substance is withheld. These may be nausea, vomiting, diarrhoea, muscular pain, uncontrollable shaking and hallucinations. Physical dependence is sometimes called **addiction**.

Not everyone who takes a mood-influencing drug develops tolerance or becomes dependent on it. Millions of people can take alcoholic drinks in moderation with no obvious physical or mental damage. Those who become dependent cannot drink in moderation. Their bodies seem to develop a need for permanently high levels of alcohol and dependent people (**alcoholics**) get withdrawal symptoms if they do not drink.

Physical and emotional dependence are very distressing states. Getting hold of the substance becomes the centre of the addicts' lives, and they lose interest in their personal appearance, their jobs and their families. Because the substances they need cannot be obtained legally or because they need the money to buy them, they turn to crime. Cures are slow, difficult and usually unpleasant.

There is no way of telling in advance which person will become dependent and which will not. Dependence is much more likely with some drugs than with others, however. These are, therefore, prescribed with great caution. Experimenting with drugs for the sake of emotional excitement is extremely unwise. Some people may become dependent on almost any substance which gives them a conscious sensation.

Some of the mood-influencing drugs will now be considered.

Stimulants

The **caffeine** in coffee, tea and cocoa is a mild stimulant and makes you more wakeful. In normal use there is no build-up of tolerance or dependence.

Amphetamines reduce fatigue and increase alertness but they also reduce accuracy and give a false sense of confidence. If taken to improve athletic performance they can cause dangerously high blood pressure. Also they are quite useless for helping examination candidates because although they increase confidence, they also reduce accuracy. Use of amphetamines can lead to tolerance and addiction.

MDMA (Ecstasy) is related to the amphetamines. It produces feelings of well-being and sociability and raises blood pressure and heart rate. Its use may be followed by a period of depression. It is thought to have caused about 70 deaths in the last 10 years, probably from overheating (heat stroke) and dehydration. Its long-term effects are not known for certain but it does temporarily damage the nerve fibres of certain brain cells.

Cocaine gives a temporary feeling of excitement but this is soon followed by depression and listlessness. It is very addictive and prolonged use constricts the arteries and causes mental disorders.

Depressants

Depressants, e.g. sedatives, act on the central nervous system to decrease emotional tension and anxiety. Different types of sedative probably affect different areas of the brain but they all lead to relaxation and, in sufficient doses, to sleep or anaesthesia. In excessive doses, they suppress the breathing centre of the brain and cause death.

Barbiturates

Barbiturates, such as phenobarbitone, are powerful sedatives, but in some cases they can be harmful or lead to addiction. As sedatives and sleeping pills they have largely been replaced by the safer benzodiazepine tranquillizers.

Tranquillizers

Some tranquillizers have been extremely valuable in treating severe mental illnesses such as schizophrenia and mania. Many thousands of mentally ill patients have been able to leave hospital and live normal lives as a result of using the tranquillizing drug **chlorpromazine**.

Nowadays, tranquillizers such as **diazepam** (Valium) and **nitrazepam** (Mogadon) are being prescribed in their millions for the relief of anxiety and tension. Some people think that these drugs are being used merely to escape the stresses of everyday life that could be overcome by a little more will-power and determination. Others think that there is no reason why people should suffer the distress of acute anxiety when drugs are available for its relief. On the other hand, some degree of anxiety is probably needed for mental and physical activity. These activities are unlikely to be very effective in people who tranquillize themselves every time a problem crops up. In some cases, use of certain tranquillizers has led to addiction.

Alcohol

The alcohol in wines, beer and spirits is a depressant of the central nervous system. Small amounts give a sense of well-being, with a release from anxiety. However, this is accompanied by a fall-off in performance in any activity requiring skill. It also gives a misleading sense of confidence in spite of the fact that one's judgement is clouded. The drunken driver usually thinks he or she is driving extremely well.

Even a small amount of alcohol in the blood increases our reaction time (the interval between receiving a stimulus and making a response). In some people, the reaction time is doubled even when the alcohol in the blood is well below the legal limit laid down for car drivers (Figure 20.4, overleaf). This can make a big difference in the time needed for a driver to apply the brakes after seeing a hazard such as a child running into the road.

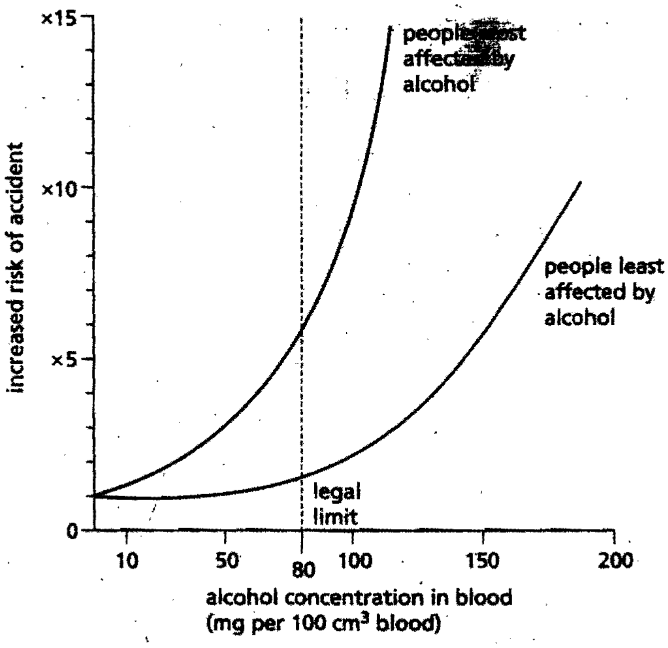


Figure 20.4 Increased risk of accidents after drinking alcohol. People vary in their reactions to alcohol. Body weight, for example, makes a difference

Alcohol causes vasodilation in the skin, giving a sensation of warmth but in fact leading to a greater loss of body heat (see p. 138). A concentration of 500 mg of alcohol in 100 cm^3 of blood results in unconsciousness. More than this will cause death because it stops the breathing centre in the brain. Ninety per cent of alcohol taken in is **detoxified** in the liver. That is, it is oxidized to carbon dioxide and water. Only 10 per cent is excreted by the kidneys. On average, the liver can oxidize about 75 mg alcohol per 1 kg body weight per hour. This rate varies considerably from one individual to the next but it indicates that it would take about 3 hours to oxidize the alcohol in a pint of beer or a glass of wine. If the alcohol intake exceeds this rate of oxidation, the level of alcohol in the blood builds up to toxic proportions; that is, it leads to **intoxication.**

Some people build up a tolerance to alcohol and this may lead to both emotional and physical dependence (alcoholism). High doses of alcohol can cause the liver cells to form too many fat droplets, leading to the disease called **cirrhosis.** A cirrhotic liver is less able to stop poisonous substances in the intestinal blood from reaching the general circulation (p. 105).

Pregnancy

Alcohol can cross the placenta and damage the fetus. Pregnant women who take as little as one alcoholic drink a day are at risk of having babies with lower than average birth weights. These underweight babies are more likely to become ill.

Heavy drinking during pregnancy can lead to deformed babies. All levels of drinking are thought to increase the risk of miscarriage.

Behaviour

Alcohol reduces inhibitions, because it depresses that part of the brain which causes shyness. This may be considered an advantage in 'breaking the ice' at parties. But it can also lead to irresponsible behaviour such as vandalism and aggression.

Moderate drinking

A moderate intake of alcoholic drink seems to do little physiological harm (except in pregnant women). But what is a 'moderate' intake?

A variety of drinks which all contain the same amount of alcohol is shown in Figure 20.5. Beer is a fairly dilute form of alcohol. Whisky, however, is about 40 per cent alcohol. Even so, half a pint of beer contains the same amount of alcohol as a single whisky. This amount of alcohol can be called a 'unit'. It is the number of units of alcohol, not the type of drink, which has a physiological effect on the body. The Health Development Agency recommends upper limits of 21–28 units for men and 14–21 units for women over a 1-week period.

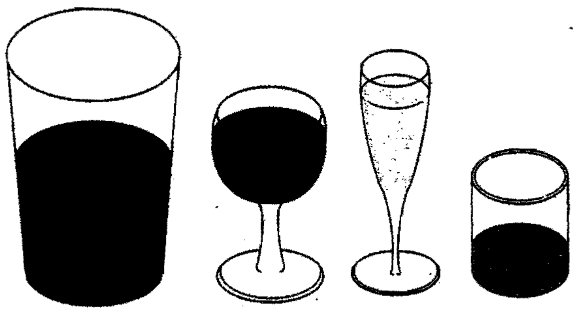


Figure 20.5 Alcohol content of drinks. All these drinks contain the same amount of alcohol (1 unit). Although the alcohol is more dilute in the beer than in the whisky, it has the same effect on the body

Hallucinogens

Cannabis

Cannabis and other extracts of Indian hemp are chewed or smoked to produce a sense of well-being, detachment and sometimes hallucinations. There does not seem to be much evidence of tolerance or emotional and physical dependence. But unstable individuals looking for more 'exciting' experiences are thought to be likely to move on from cannabis to the 'hard drugs' such as morphine and heroin.

It is difficult to conduct research into the effects of an illegal drug. Nevertheless, evidence from animal studies and human surveys is accumulating and shows that cannabis-smoking can have harmful effects on the lungs, central nervous system, immune system and reproductive function. A particular worry is the long time that the products persist in the body (days rather than hours) so that the user may be unaware of the impairment of performance, days after the last smoke.

Animal and human studies show that sperm count and sexual drive are diminished, the immune system is depressed, and learning ability and memory are impaired. These effects are in addition to the lung damage which is known to occur.

As in the case of tobacco, it may take many years to establish the full extent of the harmful side-effects of cannabis use.

Narcotics

Morphine, codeine and heroin are narcotics made from opium. Morphine and heroin relieve severe pain and produce short-lived feelings of well-being and freedom from anxiety. They can both lead to tolerance and physical dependence within weeks, and so they are prescribed with caution.

The illegal use of heroin has terrible effects on the unfortunate addict. The overwhelming dependence on the drug leads many addicts into prostitution and crime in order to obtain the money to buy it. There are severe withdrawal symptoms and a 'cure' is a long and often unsuccessful process.

Additional hazards are that blood poisoning, hepatitis and AIDS may result from the use of unsterilized needles when injecting the drug.

Codeine is a less effective analgesic than morphine, but does not lead to dependence so easily. It is still addictive if used in large enough doses.

Solvent misuse

Solvent misuse or 'glue-sniffing' is the inhaling of vapours from various organic solvents (not only glue) in order to become intoxicated. The vapours produce effects similar to drunkenness, but they are more intense and last for only a few minutes. They include dizziness and stupor, followed by a loss of co-ordination and control and eventually by unconsciousness.

The short-term after-effects are headache, nausea, vomiting and, in some cases, convulsions. After-effects which last for several weeks include runny nose, bloodshot eyes, an acne-like rash round the mouth, irritability, lethargy and depression. In the long term, the liver and kidneys may be damaged.

The number of deaths resulting from solvent misuse has been increasing steadily in the last few years. It is estimated that 46 people died in the United Kingdom in 1981, and 152 in 1990, since when it has declined to 70 (in 1998).* Death may result from (1) accidents while the person is intoxicated and out of control, (2) suffocation by the plastic bag used for inhaling, (3) choking on vomit while unconscious and (4) toxic effects of the solvent.

Solvent misusers are mostly adolescents of 14 or 15 years old or younger. They may experiment with 'glue-sniffing' as a form of rebellion against authority, to 'keep in' with their friends, to relieve boredom or for 'kicks' (risk-taking for the sake of a thrill). These reasons can, of course, be motives for other forms of drug misuse and destructive behaviour.

It is not clear whether solvent misuse leads to tolerance and dependence. Most 'glue-sniffers' do not continue once they are old enough to buy alcoholic drinks. But they are likely to drink too much, and to be tempted to move on to other drugs.

[illegible]

Checklist

- A good diet and regular exercise contribute to good health.
- Smoking and excessive drinking contribute to ill-health.
- Mood-influencing drugs may be useful for treating certain illnesses but are dangerous if used for other purposes.
- Tolerance means that the body needs more and more of a particular drug to produce the same effect.
- Dependence means that a person cannot do without a particular drug.
- Withdrawal symptoms are unpleasant physical effects experienced by an addict when the drug is not taken.
- Alcohol is a depressant drug which slows down reaction time and reduces inhibitions.
- Alcohol in a pregnant woman's blood can damage her fetus.
- Heroin and morphine are strongly addictive drugs.
- Solvent sniffing produces intoxication and has caused an increasing number of deaths.

* Data from St George's Hospital Medical School, UK