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How to get the most from this book

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8 Osmosis and plant transport



Specification points

In both GCSE Biology and Double Award Science this chapter covers specification points 2.1.1 to 2.1.6 and is called osmosis and plant transport. It covers osmosis, plasmolysis, turgidity, transpiration and the potometer, and the prescribed practical activities that demonstrate these processes.

The movement of substances into and out of cells

Cell membranes allow some substances to pass through, but prevent the movement of others; they are **selectively permeable**. Plant cells are also surrounded by a cell wall. The cell wall is totally permeable and has no role in controlling what enters or leaves the cell.

Diffusion, the random movement of a substance from where it is in high concentration to where the concentration is lower, is an important process in the transportation of substances through cell membranes. We have already met diffusion in Chapter 1.

Osmosis

Osmosis is a special type of diffusion, involving the movement of water molecules through a selectively permeable membrane. If pure water and a sucrose solution are separated by a selectively permeable membrane, (such as dialysis tubing or Visking tubing, then osmosis will occur. The water will move from where it is in a higher concentration (pure water) to where it is in a lower concentration sucrose solution); we say it moves down the concentration gradient. Another way of describing this is to say that the water moves from the weaker to the stronger solution.

Osmosis can be defined as the diffusion (movement) of water from a dilute solution to a more concentrated solution through a selectively permeable membrane.

Figure 8.1 shows how, in osmosis, water molecules move through the selectively permeable membrane but other larger molecules, such as sucrose, cannot fit through.

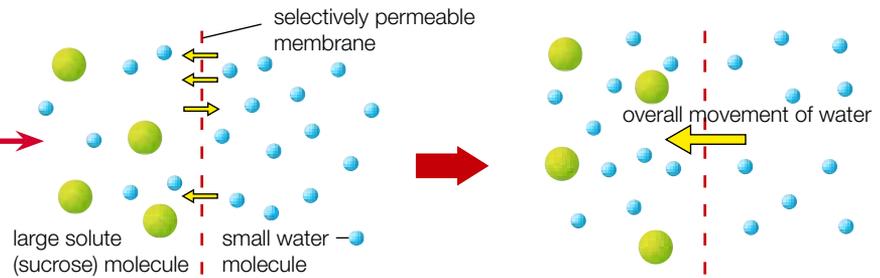
Tip



A selectively permeable membrane allows some substances through but not others. In osmosis, water can pass through the membrane because its molecules are small, but the sucrose cannot as its molecules are large.

Tips are given throughout to aid understanding.

Clear and colourful diagrams help develop knowledge.



A concentration gradient exists across a selectively permeable membrane. The water molecules can move in any direction across the selectively permeable membrane. There is a higher concentration of water on the right side of the membrane so there will be a net movement of water

The water molecules have moved through the selectively permeable membrane until there is the same concentration on each side.

▲ **Figure 8.1** Osmosis

Osmosis in cells

Water moves into or out of a cell, depending on the concentration of the solution surrounding it.

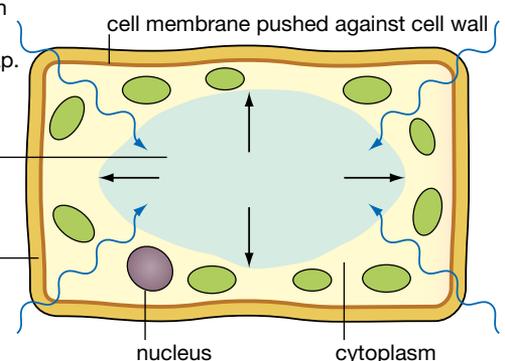
When water moves into an animal cell, the cell increases in volume, stretching the cell membrane. If this continues, the cell membrane will eventually split and the cell will burst. This is called **lysis**.

When water enters a plant cell, the vacuole increases in size, pushing the cell membrane against the cell wall. The force of the membrane pushing against the stiff cell wall increases the pressure in the cell, making it firm or **turgid**. This **turgor** pressure created by the cell wall prevents too much water from entering and thus stops the cell from bursting, as happens in animal cells. It also gives plant cells support and in non-woody plants this is essential in keeping the plant upright.

Water flows in from a higher concentration of water molecules outside the cell to a lower concentration of water in the cell sap.

Vacuole fills with water, pushing the cytoplasm against the cell wall.

Cell wall stretches slightly – cell becomes turgid.



▲ **Figure 8.2** Turgor in plant cells

The importance of turgor in providing support can be seen when there is a shortage of water. When plant cells do not receive enough water, they cannot remain turgid and **wilting** occurs. Cells that are not turgid are described as being **flaccid**.

Tip



For a plant cell to be turgid, the concentration of the cell must be greater than the solution surrounding the cell.

Tip



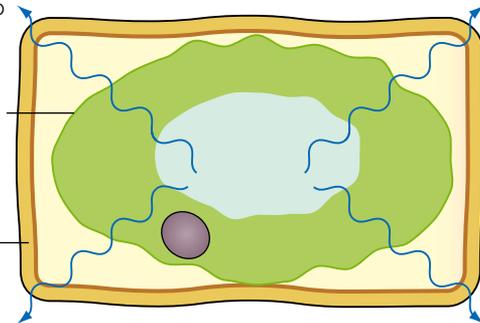
A cell will only become plasmolysed if the solution surrounding the cell is more concentrated than the cell itself.

If a plant cell loses too much water by osmosis, a condition called **plasmolysis** occurs. During plasmolysis, so much water leaves the cell that the cell's contents shrink, pulling the cell membrane away from the cell wall. Although loss of turgor and wilting is a common occurrence in many plants, plasmolysis is much less likely in healthy plants. This is just as well, as plasmolysed cells are unlikely to survive!

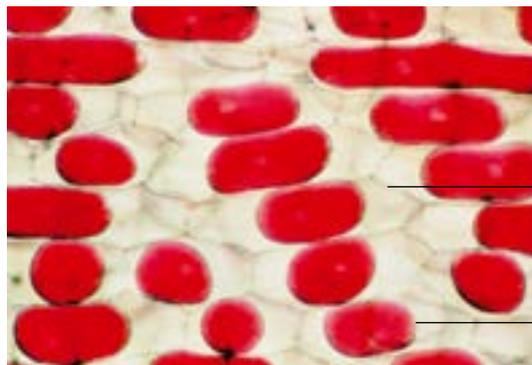
Water flows from a higher concentration of water molecules in the cell sap to a lower concentration outside the cell.

Cell membrane pulls away from the cell wall as the vacuole loses water.

Cell wall becomes soft – cell becomes plasmolysed.



▲ **Figure 8.3** Plasmolysis in plant cells



Cell wall

Cell membrane pulled away from cell wall

▲ **Figure 8.4** Plasmolysis in red onion

You should be able to use a microscope to observe turgid and plasmolysed cells. Revise how to use a microscope in Chapter 1.

Consolidate learning with regular Test Yourself questions.

Show You Can questions are designed for class discussion or to enhance individual understanding.

Test yourself



- 1 Define the term osmosis.
- 2 Explain the difference between osmosis and diffusion.
- 3 Explain the importance of the plant cell wall in turgor.

Show you can



Explain why it is important that the cells in plant roots have a higher concentration than the surrounding soil water.

Prescribed practical



Enhance practical and enquiry skills with full coverage of the CCEA prescribed practicals.

Practical 2.1: Investigate the process of osmosis by measuring the change in length and mass of plant tissue or model cells using Visking tubing

a) Investigating osmosis by measuring the change in mass of plant tissue in solutions of different concentrations

Procedure

- 1 You will be given a range of sucrose solutions of different concentrations, such as 5%, 10%, 15% and 20%.
- 2 Set up and label a number of beakers, each with a different sucrose solution. There should also be a beaker containing water only.
- 3 Using a cork borer, cut five potato cylinders.
- 4 Weigh each cylinder of potato and add to one of the beakers.
- 5 Leave the beakers for at least an hour.
- 6 Pat dry and reweigh the potato cylinders.
- 7 Complete the table below with your results.

| Percentage concentration of sucrose in beaker/% | Initial mass/g | Final mass/g | Difference in mass/g | Percentage change in mass/% |
|---|----------------|--------------|----------------------|-----------------------------|
| 0 (water) | | | | |
| 5 | | | | |
| 10 | | | | |
| 15 | | | | |
| 20 | | | | |

- 8 Draw a graph of percentage change in mass against concentration of sucrose using axes similar to the outline drawn on the right. When drawing this graph you should use a best-fit line (not a point-to-point graph).

- 9 Describe and explain your results.

In this investigation you need to be able to calculate percentage change. An example of how to do this is shown below.

Example



The mass of a potato cylinder changed from 11.45 g to 9.04 g. Calculate the percentage change.

Answer

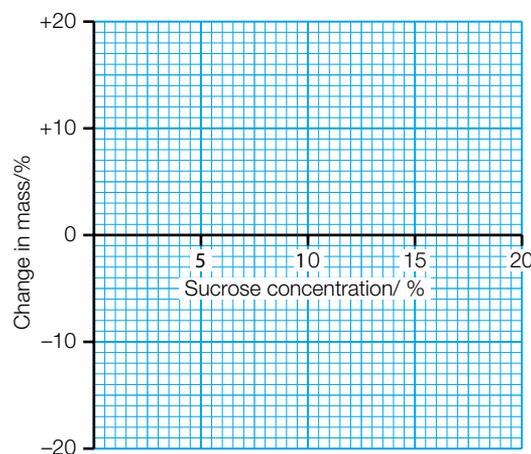
$$11.45 - 9.04 = 2.41 \text{ (decrease)}$$

$$2.41/11.45 \times 100 = -21.5\%$$

You can complete a similar investigation by measuring the length of the potato cylinders rather than mass.

Questions and sample data

- 1 Explain how you would use your graph to find the concentration of sucrose that has the same concentration as the potato.
- 2 Suggest why you should use a best-fit line, rather than point to point, in this investigation.



▲ **Figure 8.7** Investigating percentage change in mass of potato cylinders in a range of sucrose solutions.



The table below shows the results of an investigation measuring length of potato cylinders in different concentrations.

| Concentration of sucrose solution/% | Length of potato cylinder/mm | | | |
|-------------------------------------|------------------------------|----------------|--------|----------|
| | At start | 24 hours later | Change | % Change |
| Water | 51 | 57 | +6 | 11.7 |
| 5% sucrose | 50 | 53 | +3 | 6 |
| 10% sucrose | 48 | 46 | -2 | -4.2 |
| 15% sucrose | 55 | 50 | -5 | -9.1 |

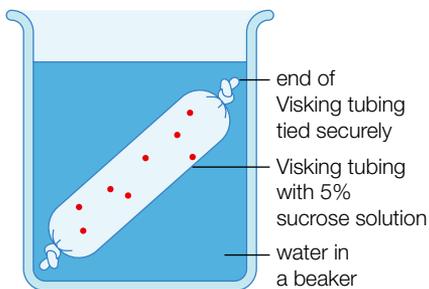
- Using the table, estimate the concentration of sucrose that could have the same concentration as the potato.
- Explain why it is important in this investigation to use percentage change rather than just change in length.
- Suggest two reasons why it is more accurate to use mass rather than length of potato cylinders in this investigation.

b) Investigating osmosis by using Visking tubing

Visking tubing is selectively permeable and can therefore be used to model the movement of substances through the cell membrane.

Procedure

- Add 5% sucrose to a section of Visking tubing, ensuring the tubing is sealed securely at each end.
- Dry the outside of the tubing if necessary and weigh the tubing and contents.
- Add the Visking tubing to a beaker of water and leave for at least 1 hour.



▲ **Figure 8.3** Using Visking tubing in an osmosis investigation

- Pat dry the outside of the Visking tubing and reweigh.
- Describe and explain the results obtained.

Tips



- ▶ The general principles involving water movement in the three investigations described above are the same: the water will move from a weaker to a stronger solution.
- ▶ In the investigations with potato, the cell membranes of the potato cells are selectively permeable membranes. In the Visking tubing investigation, the Visking tubing itself is selectively permeable.



▲ **Figure 8.6** Adding sucrose solution to Visking tubing.

Tip



It is very important that the Visking tubing is tied tightly at both ends in this investigation.

Transpiration

Much of the water that enters the leaves of a plant evaporates into the atmosphere. This loss of water by evaporation is called **transpiration**. Transpiration takes place in the **spongy mesophyll cells** in plant leaves, through the air spaces and out of the **stomata** (small pores).

This continuous movement of water through a plant (the transpiration stream) is very important for four reasons:

- 1 The supply of water to the leaves acts as a raw material for **photosynthesis**.
- 2 The movement of water **transports minerals** through the roots and up the stem to the leaves and other parts of the plant.
- 3 As water passes through the plant, it enters cells by osmosis to provide **support** through turgor.
- 4 Providing water for the process of **transpiration** itself.

Plants often need to reduce water loss by transpiration. They do this by closing the stomata, which are most common on the underside of leaves. The stomata are necessary to allow gases to enter and leave the leaf, but they can be closed on occasions when it is important to conserve water.

Tip

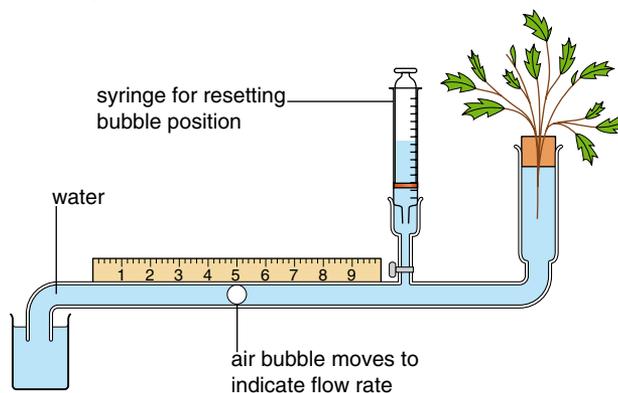


When covering transpiration it is useful to revise the structure of the leaf; see Chapter 2.

Measuring water uptake using a potometer

The bubble potometer is a piece of apparatus designed to measure water uptake in a leafy shoot. As water evaporates from the leaves of the cut shoot, the shoot sucks water up through the potometer. The distance an air bubble moves in a period of time can be used to calculate the rate of water uptake.

The reservoir, or syringe, allows the apparatus to be reset so that replicate results can be recorded or the water uptake can be measured in different environmental conditions. Air leaks will hinder the uptake of water into the plant, so it is important that the potometer apparatus is properly sealed, particularly at the junction between the shoot and the neck of the potometer. To prevent the development of unwanted air bubbles in the water column entering the plant, it is necessary to assemble the apparatus under water initially.



▲ **Figure 8.8** A bubble potometer

A bubble potometer can be used to measure how environmental conditions such as **wind speed**, **temperature** or **humidity** affect the rate of water uptake. Conditions that increase the rate of evaporation and transpiration, such as higher temperatures or higher wind speed (through using a fan), will increase the rate of water uptake. Higher levels of humidity, created through covering the shoot with a polythene bag, will reduce evaporation and transpiration and therefore slow the rate of water uptake by the shoot.

Obviously, when changing a particular environmental factor (such as wind speed) to show how it affects water uptake, it is necessary to keep other environmental factors constant, including temperature, humidity and light, etc. This ensures that the results are **valid**. Replicated results will help ensure that the results are **reliable**.

Leaf surface area, while not an environmental factor, will also affect transpiration rates. Larger leaves will have more stomata, through which water can evaporate and diffuse. You should be able to plan an experiment to investigate the effect of leaf surface area on transpiration rate.

The potometer can accurately measure the volume of water taken up by the shoot, but it cannot give an absolute value for transpiration itself. It is impossible to calculate how much of the water taken up by the plant is actually transpired through the leaf surface. Some of the water will be used in photosynthesis and in providing support through turgor, so the volume transpired will inevitably be less than the volume taken into the shoot. However, it is an excellent method for comparing rates in different conditions.

Transpiration rates can also be measured using a **weighing method**, by weighing how much water a plant loses over a period of time.

Tip



If you are asked to give three environmental factors that affect transpiration, give wind speed, temperature and humidity. Do not give leaf surface area, as this is not an environmental factor.

Test yourself

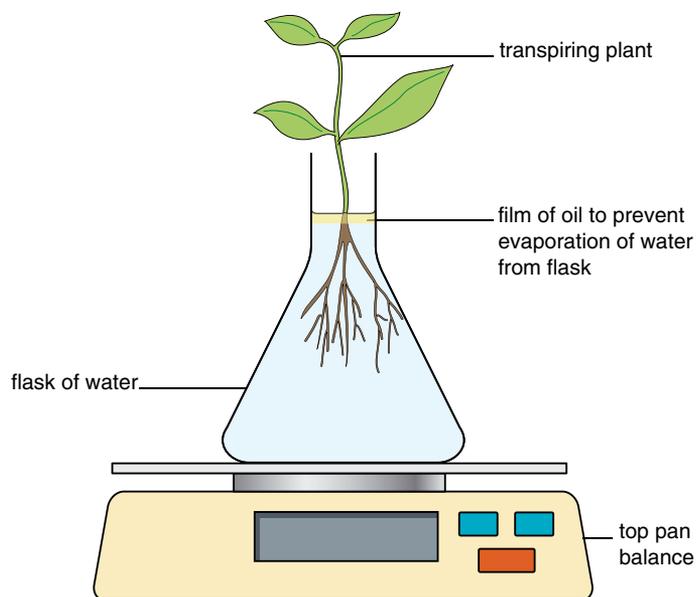


- 4 Define the term transpiration.
- 5 State three environmental factors that affect transpiration rate.
- 6 State four reasons why plants need water.

Show you can



Explain why the rate of transpiration in a plant and water uptake are closely linked, but will not be exactly the same.



▲ **Figure 8.9** A weight potometer

Prescribed practical



Practical 2.2: Use a potometer (bubble or weight potometer and/or washing line method) to investigate the factors affecting the rate of water uptake by a plant

a) Using the bubble potometer to investigate the factors affecting the rate of water uptake by a plant shoot

Procedure

- 1 Set up a bubble potometer by attaching a shoot to the neck of the apparatus. Take the precautions to prevent air leaks as described earlier.
- 2 Calculate the rate of movement of the bubble over time for a particular environmental condition, such as still air.
- 3 Repeat to obtain more reliable results.
- 4 Adjust the environmental conditions. For example, use a fan to create windy conditions.
- 5 Repeat steps 2 and 3 above.
- 6 Record your results in a table similar to the one below.

Table 8.3 Using a bubble potometer to compare transpiration rates

| Environmental condition | Position of bubble/mm | | Difference in bubble position/mm | Time/minute | Rate of movement/mm/minute |
|-------------------------|-----------------------|--------|----------------------------------|-------------|----------------------------|
| | At start | At end | | | |
| No wind (still air) | | | | | |
| Windy | | | | | |

Similar investigations can be carried out using a weight potometer. When using a weight potometer, a table similar to the one below can be used.

Table 8.4 Using a weight potometer to compare transpiration rates

| Environmental condition | Mass of beaker and shoot/g | | Difference in mass/g | Time/hour | Rate of change of mass/g/hour |
|-------------------------|----------------------------|--------|----------------------|-----------|-------------------------------|
| | At start | At end | | | |
| No wind (still air) | | | | | |
| Windy | | | | | |

Questions and sample data

When comparing transpiration rates in different environmental conditions, it is not always necessary to calculate the 'rate' of water loss. The table below shows typical results for using a weight potometer to compare water loss (transpiration rate) in two different humidity levels.

Table 8.5 Comparing transpiration rates in different humidity levels

| Environmental condition | Mass of beaker and shoot/g | | | |
|--|----------------------------|----------------|----------|---------------------|
| | At start/g | After 24 hours | Change/g | Percentage change/% |
| 'Normal' humidity | 114.22 | 108.47 | 5.75 | 5.03 |
| High humidity (shoot covered with clear plastic bag) | 121.56 | 118.02 | 3.54 | 2.91 |

- 1 Suggest why a top-pan balance with two decimal points was used in this investigation.
- 2 Describe and explain the difference in water loss in the two conditions.

b) Using the washing line method to investigate the factors affecting the rate of water loss from plant leaves

Procedure

- 1 Detach six leaves from a tree.
- 2 Smear petroleum jelly over the cut stalk to make it waterproof.
- 3 Measure the mass of each leaf and then, using paper clips, hang them on a line of string suspended between two retort stands.
- 4 Suspend half the leaves on a line of string at a high temperature (such as 30 °C) and the other half should be suspended at a lower temperature (such as 20 °C), in order to compare the effect of temperature on water loss by a leaf.
- 5 After 24 hours, reweigh the leaves and calculate the average loss of mass for each environment condition.
- 6 Describe and explain the results obtained.

Practice questions

Prepare students for assessment with topic-specific practice questions.

- 1 a) Define the term osmosis. (1 mark)
 - b) Explain the role of osmosis in providing support in plants. (3 marks)
- 2 The diagram below shows Visking tubing containing 5% sucrose solution surrounded by a solution of 10% sucrose in a beaker.

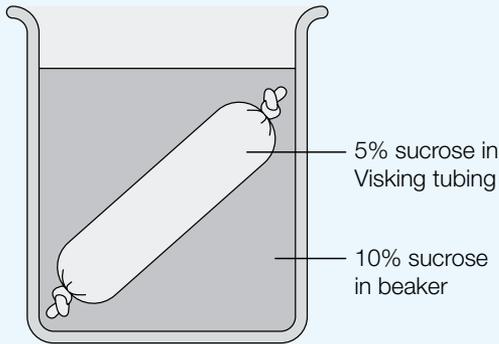


Figure 8.10

- a) Suggest how the appearance of the Visking tubing will change after 24 hours. Explain your answer. (3 marks)
 - b) A student carried out a similar investigation, but she found that there was no change in her Visking tubing after 24 hours. Suggest an explanation for this. (2 marks)
- 3 A farmer put too much fertiliser onto part of a field. A few days later many of the cells in the roots of his plants had become plasmolysed. Suggest why this occurred. (2 marks)

- 4 Some students were asked to investigate if more water was lost by transpiration through the upper or the lower surface of leaves. They collected 20 leaves and separated them into two groups. They covered the upper surface of the first group and the lower surface of the second group in petroleum jelly. The leaves were weighed on a top-pan balance and then attached to a line running between two retort stands with paper clips. The leaves were reweighed 24 hours later. A summary of the results is recorded in the following table.

Table 8.6

| Leaf treatment | Average mass/g | | Percentage change after 24 hours |
|--|----------------|------------------------|----------------------------------|
| | At start | After 24 hours on line | |
| Upper surface covered in petroleum jelly | 4.22 | 3.37 | 20.14 |
| Lower surface covered in petroleum jelly | 4.68 | 4.26 | 8.97 |

- a) Describe and explain the results in the table. (2 marks)
- b) Why were 10 leaves used for each treatment? (1 mark)
- c) State **two** variables that should have been controlled in this investigation. (2 marks)
- d) State one procedure that is necessary when setting up the investigation to ensure valid results. (1 mark)

- 5 a) Briefly describe two ways you would try to avoid air leaks when setting up a bubble potometer. (2 marks)
- b) A student carried out an investigation into the effect of wind speed on transpiration rate using a bubble potometer.
- i) Suggest how the wind speed could be changed in this investigation. (1 mark)

The graph below shows how the distance the bubble moved in 10 minutes changed with different wind speeds.

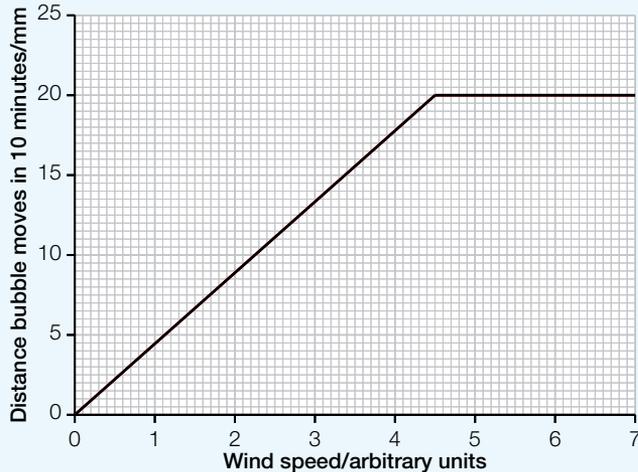


Figure 8.11

- ii) Describe and explain these results. (4 marks)
- iii) State **two** variables that should have been controlled in this investigation. (2 marks)
- iv) Give **one** advantage in using a weight potometer, compared with a bubble potometer. (1 mark)

- 6 Dandelion stalks have two layers: an outer layer that is largely impermeable to water and an inner layer that is permeable to water. A small section of dandelion stalk was removed, as is shown in the diagram below, and placed in a beaker of water.

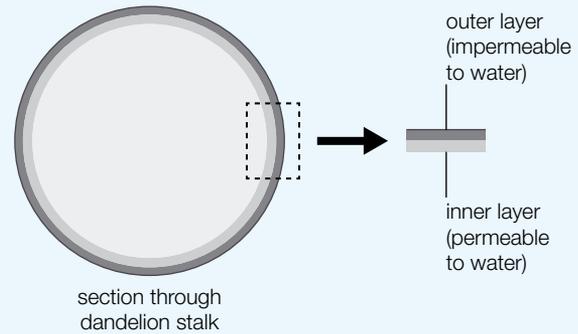


Figure 8.12

After two hours in the water, the section of stalk had changed, as shown in the diagram below.

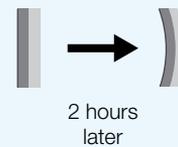


Figure 8.13

- a) Describe and explain the result shown. (3 marks)
- b) Another section of stalk was placed in a weak sugar solution and left for two hours. After two hours, the section of dandelion stalk had not changed shape. Explain this observation. (2 marks)

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