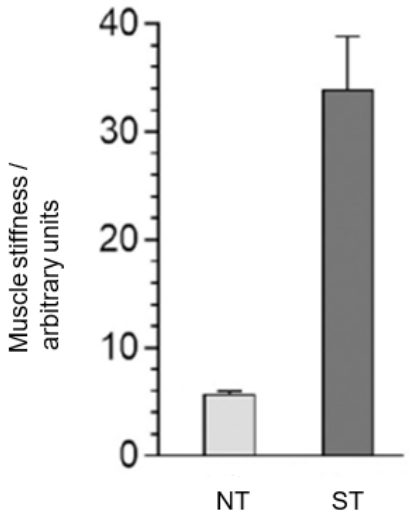
D2.3 Water potential [86 marks]

1. [Maximum mark: 7]

Titin is a protein found in sarcomeres which affects the stiffness of muscle. Muscles with greater stiffness are more resistant to elongation or shortening. The role of titin in muscle was studied using mutant mice with short titin fibres in their skeletal muscle (ST) which were compared against a control group of mice with titin fibres of normal length (NT).



[Source: adapted from Ambjorn Brynnel, Yaeren Hernandez, Balazs Kiss, Johan Lindqvist, Maya Adler, Justin Kolb, Robbert van der Pijl, Jochen Gohlke, Joshua Strom, John Smith, Coen Ottenheijm, Henk L Granzier (2018). *Downsizing the molecular spring of the giant protein titin reveals that skeletal muscle titin determines passive stiffness and drives longitudinal hypertrophy*. eLife. 7:e40532 https://doi.org/10.7554/eLife.40532.]

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

. . . . . .

. . . . . .

. . . . . .

(a.ii) Suggest a variable that needs to be kept constant in both groups of mice to ensure reliable results [1]

. . . . . .

. . . . . .

. . . . . .

(a.iii) Comment on the significance of the error bars for muscle stiffness shown in the graph. [1]

. . . . . .

. . . . . .

. . . . . .

(b) From the results of this investigation, suggest a possible consequence of shorter titin on movement. [1]

. . . . . .

. . . . . .

. . . . . .

(c) Explain how marine mammals are adapted for movement in water. [3]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

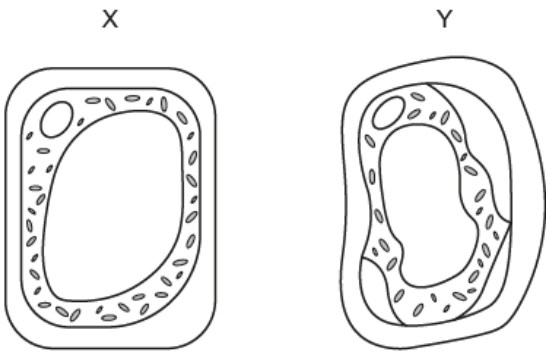
. . . . . .

. . . . . .

. . . . . .

2. [Maximum mark: 1]

Two plant cells are shown as they appear in different solutions X and Y.



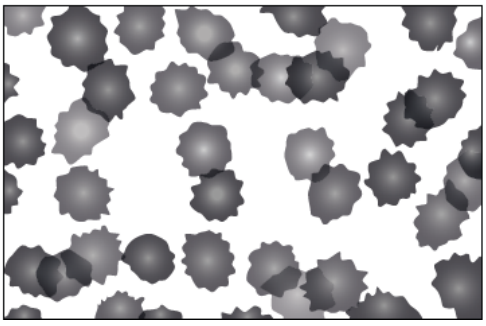
What happens to water and pressure potential inside the cell if it is moved from solution X to solution Y?

[1]

	Water potential	Pressure potential
A.	does not change	decreases
B.	decreases	decreases
C.	does not change	increases
D.	increases	increases

3. [Maximum mark: 1]

The image shows human blood cells immersed in a solution.



What can be deduced from the image?

A. The solution is hypotonic as the cells are crenated.

B. The solution is hypotonic as the cells are turgid.

C. The solution is hypertonic as the cells are crenated.

D. The solution is hypertonic as the cells are turgid.

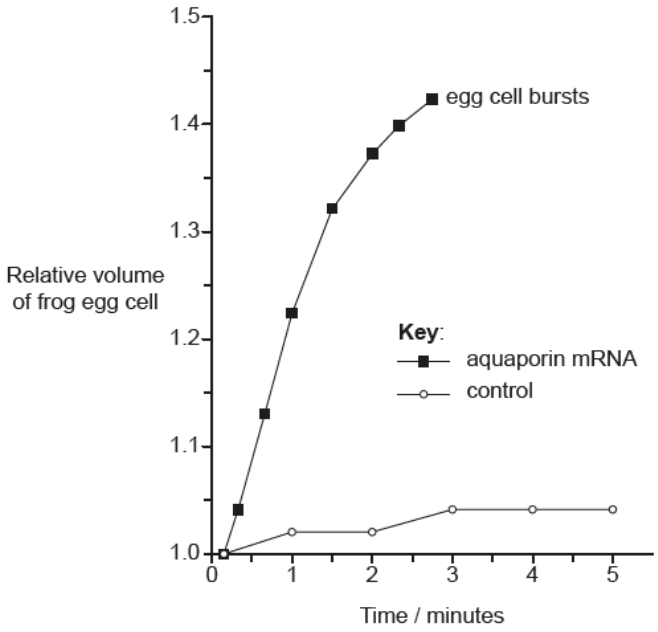
[1]

4. [Maximum mark: 10]

In the early 1990s, investigations involving egg cells from the African clawed frog (*Xenopus laevis*) led to the discovery of membrane channel proteins called aquaporins.

In one investigation, scientists injected 10 frog egg cells with a solution containing mRNA encoding for an aquaporin, and another 10 frog egg cells with distilled water (control cells). All the frog egg cells were then incubated in a hypotonic solution. The volume of the frog egg cells was then measured during a period of five minutes.

The graph shows the mean results of the investigation.



[Source: Reproduced from Gregory M. Preston et al., Appearance of Water Channels in Xenopus Oocytes Expressing Red Cell CHIP28 Protein, DOI: 10.1126/science.256.5055.385. 1992, AAAS.]

(a) State the direction of net movement of water across the plasma membrane of all the frog egg cells between 0 and 3 minutes. [1]

. . . . . .

. . . . . .

. . . . . .

(b.i) Explain the reasons for the different results obtained for the frog egg cells with aquaporin mRNA and the control frog egg cells.

[2]

(b.ii) Discuss the role of aquaporins in the collecting ducts of a human kidney when the water content of blood is too low. [3]

(c) Outline the reason that the results are displayed as mean relative volumes rather than mean volumes. [1]

(d) Comment on the reliability of the results of this investigation. [1]

(e) In investigations of this type, scientists usually find that there is a short time delay between the introduction of mRNA into a cell and the effect on the cell. Explain this observation. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

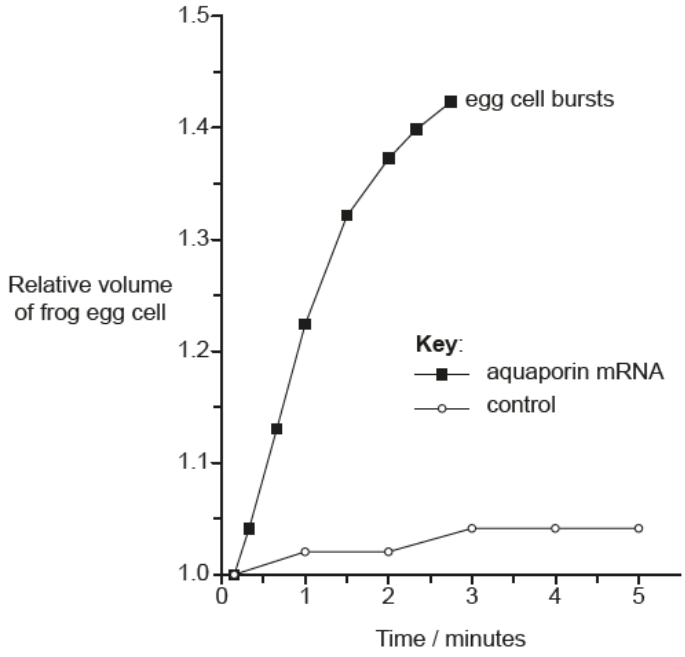
. . . . . .

5. [Maximum mark: 7]

In the early 1990s, investigations involving egg cells from the African clawed frog (*Xenopus laevis*) led to the discovery of membrane channel proteins called aquaporins.

In one investigation, scientists injected 10 frog egg cells with a solution containing mRNA encoding for an aquaporin, and another 10 frog egg cells with distilled water (control cells). All the frog egg cells were then incubated in a hypotonic solution. The volume of the frog egg cells was then measured during a period of five minutes.

The graph shows the mean results of the investigation.



[Source: Reproduced from Gregory M. Preston et al., Appearance of Water Channels in Xenopus Oocytes Expressing Red Cell CHIP28 Protein, DOI: 10.1126/science.256.5055.385. 1992, AAAS.]

(a) State the direction of net movement of water across the plasma membrane of all the frog egg cells between 0 and 3 minutes. [1]

. . . . . .

. . . . . .

. . . . . .

(b.i) Distinguish between the results shown for the frog egg cells with aquaporin mRNA and the control egg cells. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b.ii) Explain the role of aquaporins in the movement of water across cell membranes. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Outline the reason that the results are displayed as mean relative volumes rather than mean volumes. [1]

. . . . . .

. . . . . .

. . . . . .

(d) Comment on the reliability of the results of this investigation. [1]

. . . . . .

. . . . . .

. . . . . .

6. [Maximum mark: 15]

Water is one of the most abundant molecules on Earth. Living organisms must maintain homeostatic levels of water to survive.

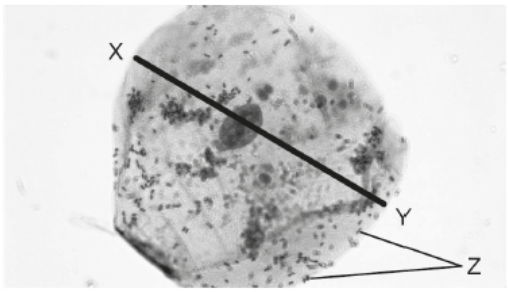
(a) Outline how the cohesive properties of water benefit living organisms. [4]

(b) Outline how environmental factors affect the rate of transpiration in plants. [4]

(c) Explain the process of osmosis with reference to its effects on plant cells. [7]

7. [Maximum mark: 5]

The micrograph shows a human cheek cell magnified with a light microscope.



[Source: Fox, E. (2022, February 12). Micrograph human cheek epithelial cells methylene blue 1000X p000018. OER Commons. https://oercommons.org/courseware/lesson/89980.]

(a) Calculate the width of the cheek cell from X to Y. [1]

. . . . . .

. . . . . .

. . . . . .

(b) Explain what causes the irregular shape of the cheek cells rather than the uniform shape of plant cells. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Describe what would happen to the cheek cell if it was placed in a hypertonic salt solution. [1]

. . . . . .

. . . . . .

. . . . . .

(d) In addition to the cheek cell, the micrograph shows smaller single cells. Two of these cells are labelled Z. Predict with a reason what the single cells could be. [1]

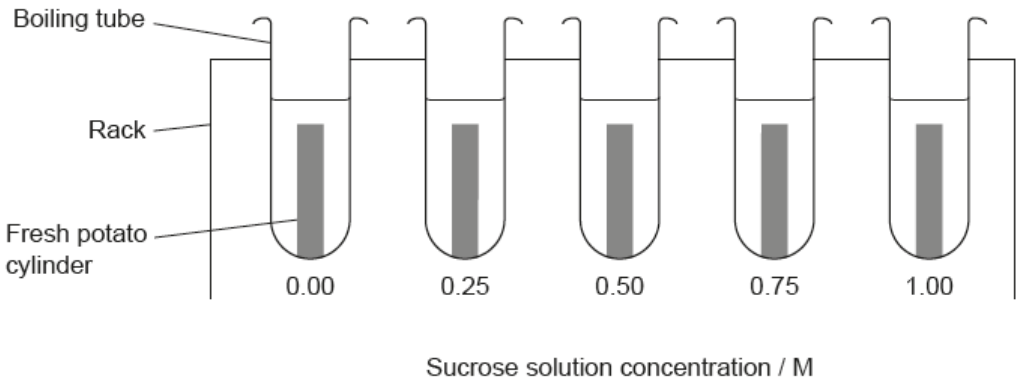
. . . . . .

. . . . . .

. . . . . .

8. [Maximum mark: 1]

In an experiment, a student placed five fresh potato cylinders of equal size in solutions of varying sucrose concentrations.



On completion of the experiment, the student concluded that the concentration of sucrose isotonic with the potato was 0.30 M. In how many of the solutions did the potato cylinders lose mass?

A. 1

B. 2

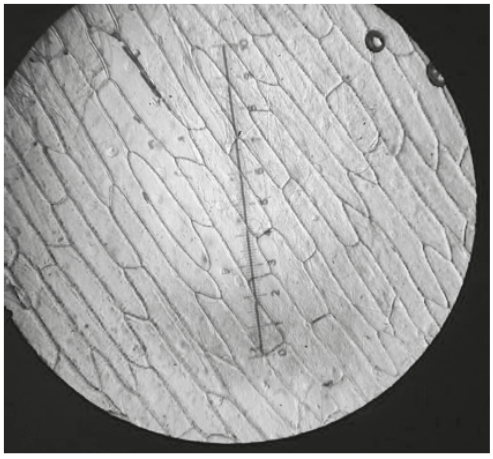
C. 3

D. 4

[1]

9. [Maximum mark: 1]

Onion (*Allium cepa*) epidermis was placed in pure water and observed with a light microscope using high magnification.



What would happen to these cells if they were transferred to a hypertonic solution?

A. Cells would gain mass.

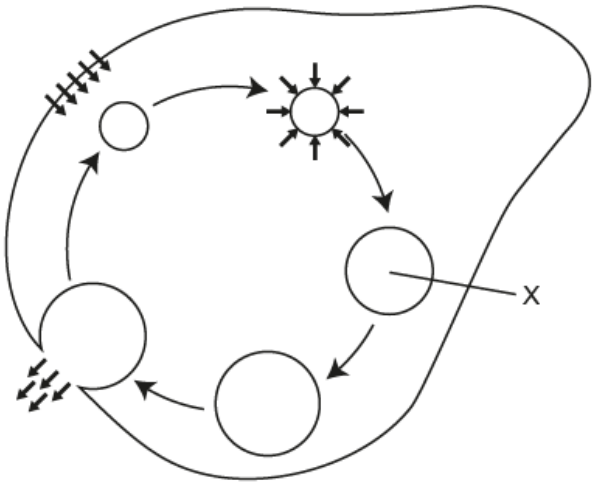
B. Cells would take in water by osmosis and swell.

C. Cells would burst open, releasing their content.

D. Cell membranes would detach from walls at some points. [1]

10. [Maximum mark: 1]

The diagram refers to questions 2 and 3. It shows a heterotrophic, unicellular, freshwater organism that has been placed in distilled water. The short arrows show movement of water and the long arrows show a sequence of steps.



What would happen if the unicellular organism was placed in a solution slightly less concentrated than the cytoplasm of the cell, rather than in distilled water?

A. The cell would become larger.

B. More water would be expelled from the cell.

C. X would fill more slowly.

D. X would not appear. [1]

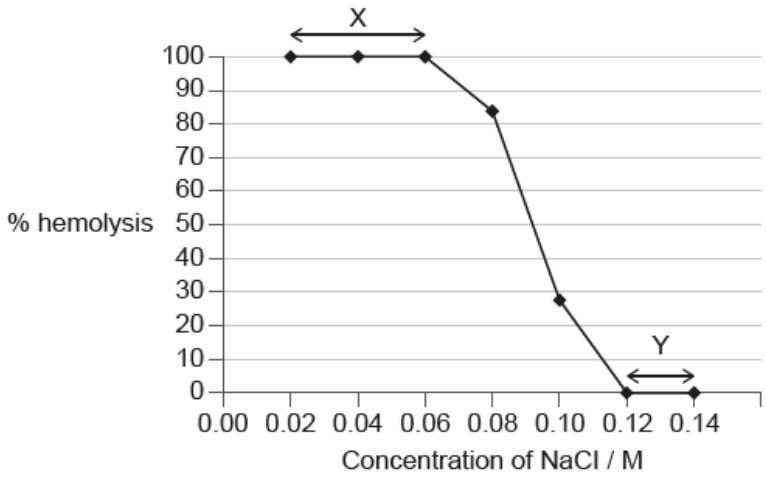
. . . . . .

. . . . . .

. . . . . .

11. [Maximum mark: 1]

Red blood cells from a small mammal were immersed in NaCl (sodium chloride) solutions of different concentrations for 2 hours. The graph shows the percentage of hemolysed (ruptured) red blood cells at each concentration.



[Source: Zaidan, T. , de Matos, W. , Machado, É. , Junqueira, T. , Vicentini, S. , Presta, G. and Santos-Filho, S. (2010)
Cellular effects of an aqueous solution of Losartan® on the survival of Escherichia coli AB1157 in the presence
and absence of SnCl2, and on the physiological property (osmotic fragility) of the erytrocyte. *Advances in Bioscience and Biotechnology*, 1, 300–304. doi: 10.4236/abb.2010.14039. Available at https://www.scirp.org/pdf/ABB20100400005_18844979.pdf Licensed under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).]

[1]

What can be deduced from the graph?

A. At Y, the net movement of Na ions between red blood cells and the NaCl solutions is zero.

B. At X, Na and Cl ions disrupt the structure of cell membranes.

C. At Y, the hypertonic NaCl solutions diffuse into the red blood cells.

D. At X, water has moved by osmosis into the red blood cells.

. . . . . .

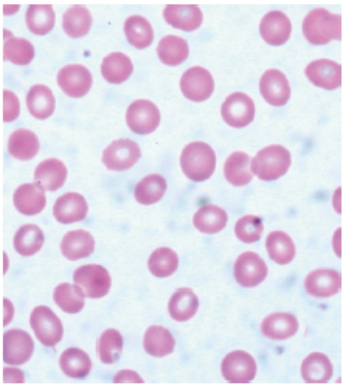
. . . . . .

. . . . . .

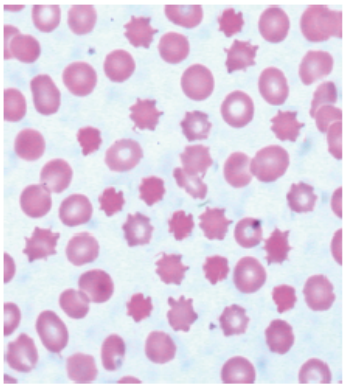
12. [Maximum mark: 1]

In an experiment on osmosis, red blood cells were immersed in a salt solution for two hours. The micrographs show the appearance of these cells before and after immersion in the salt solution.

before immersion



after immersion



[Source: Ed Uthman, Acanthocytes, from peripheral blood [image online] Available at: https://en.wikipedia.org/wiki/Acanthocyte#/media/File:Acanthocytes,_Peripheral_Blood_(3884092551).jpg This file is licensed under the Creative Commons Attribution 2.0 Generic (CC BY 2.0) https://creativecommons.org/licenses/by/2.0/ Source adapted.]

What explains the observed changes?

A. The salt solution was hypertonic and entered the red blood cells.

B. The salt solution was hypotonic and disrupted the membranes of the red blood cells.

C. The salt solution was hypertonic and water moved into it from the red blood cells.

D. The salt solution was hypotonic and mineral salts were lost from the red blood cells.

[1]

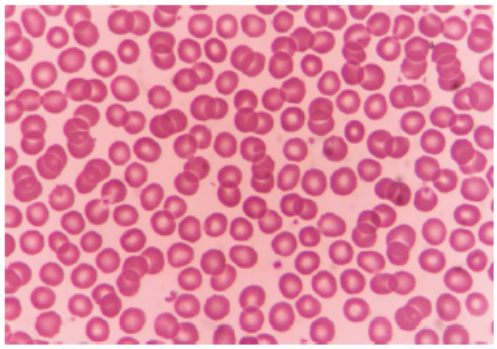
. . . . . .

. . . . . .

. . . . . .

13. [Maximum mark: 5]

(a) The image shows human red blood cells.



[1]

[Source: someoneice/123rf.com.]

Outline what will happen to human red blood cells if transferred to distilled water.

. . . . . .

. . . . . .

. . . . . .

(b) Stem cells can be used to treat Stargardt's disease. State **one** other condition treated using stem cells. [1]

. . . . . .

. . . . . .

. . . . . .

(c) Explain the propagation of nerve impulses along the membrane of a neuron. [3]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

14. [Maximum mark: 15]

Substances can move into and out of cells through the cell membrane.

(a) Outline the significance of surface area to volume ratio in the limitation of cell size. [4]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

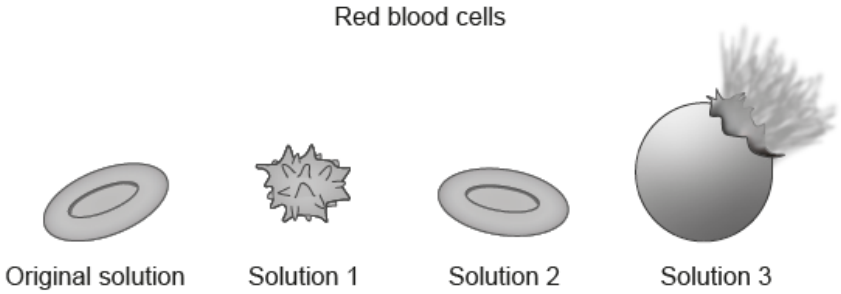
. . . . . .

(b) Describe transport across cell membranes by osmosis. [4]

(c) Explain the adaptations of the small intestine to its function. [7]

15. [Maximum mark: 1]

The images show samples of red blood cells that were placed in different concentrations of salt solutions.



Which process explains the observations shown in the images?

A. Active transport

B. Exocytosis

C. Facilitated diffusion

D. Osmosis [1]

. . . . . .

. . . . . .

. . . . . .

16. [Maximum mark: 1]

A human organ is being prepared for transplant. In what type of solution must it be bathed?

A. A hypertonic solution

B. A hypotonic solution

C. Pure water containing no solutes

D. A solution with the same osmolarity as the organ tissue [1]

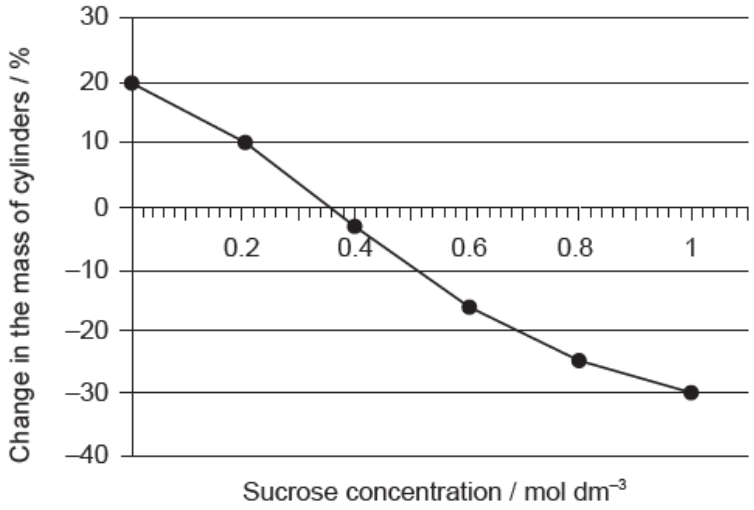
. . . . . .

. . . . . .

. . . . . .

17. [Maximum mark: 5]

An experiment was carried out to study osmosis in plant cells. Small cylinders of zucchini (*Cucurbita pepo*) were cut and placed in different sucrose solutions at 25 °C. The figure shows the percentage changes in mass after 24 hours.



(a) Estimate the solute concentration of the zucchini cells. [1]

. . . . . .

. . . . . .

. . . . . .

(b) If a zucchini is allowed to dry in the open air, predict how the osmolarity of the zucchini cells would change. [1]

. . . . . .

. . . . . .

. . . . . .

(c) Explain **one** reason for calculating the percentage changes in mass. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(d) Predict what would happen to a red blood cell placed in distilled water. [1]

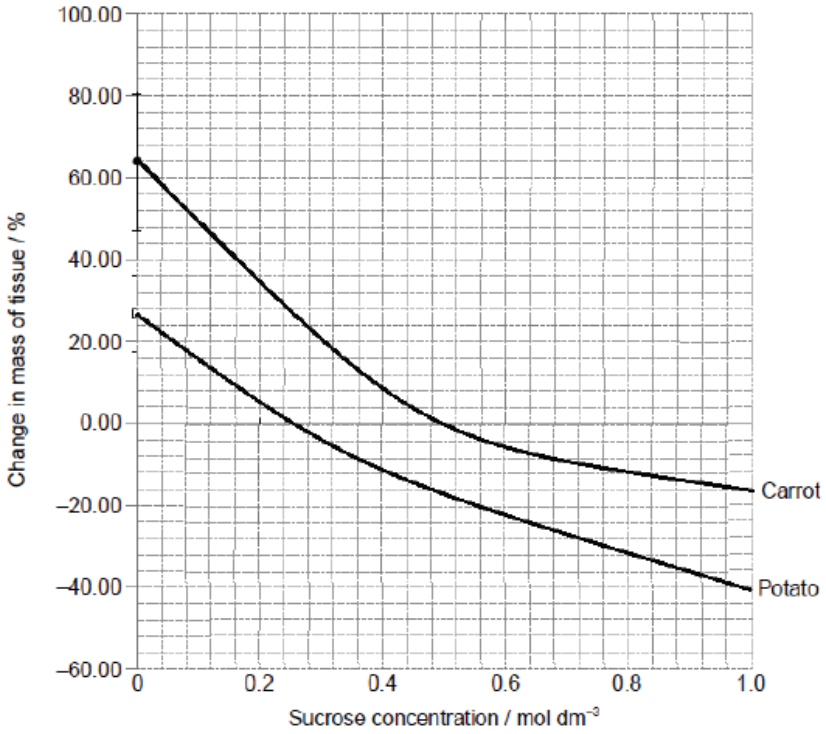
. . . . . .

. . . . . .

. . . . . .

18. [Maximum mark: 7]

An experiment was carried out on osmosis in carrot (*Daucus carota*) root tissue and potato (*Solanum tuberosum*) tuber tissue. Similar sized pieces of tissue were cut and soaked in different sucrose solutions for 24 hours. The results are shown in the graph below.



(a) Using the graph, estimate isotonic sucrose solutions for potato tissue and carrot tissue.

Potato:

Carrot: [2]

. . . . . .

. . . . . .

. . . . . .

(b) Suggest a reason for the difference in the isotonic points for the potato and the carrot tissues. [1]

. . . . . .

. . . . . .

. . . . . .

(c) From the evidence provided by the graph, evaluate the reliability of these data. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(d) Explain **one** reason for calculating the percentage change in mass. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

19. [Maximum mark: 1]
Which process(es) occur(s) by osmosis?

I. Uptake of water by cells in the wall of the intestine

II. Loss of water from a plant cell in a hypertonic environment

III. Evaporation of water from sweat on the skin surface

A. I only

B. I and II only

C. II and III only

D. I, II and III

[1]

. . . . . .

. . . . . .

. . . . . .