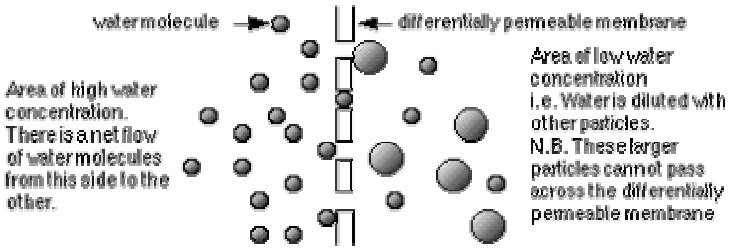
GCSE Coursework

The aim of this experiment is to investigate the movement of water into and out of plant cells by osmosis. The cells chosen for study will be taken from potato tubers as they provide a ready supply of uniform material.

Any substance dissolved in water is called a solute; a solvent is a liquid that is able to dissolve another substance, called a solute, to form a solution.

The water content of plants varies depending on environmental conditions. In Land plants this water plays a vital role in the support of tissues and the transport of materials around the organism. Lack of water leads to wilting and eventually death. Water is mainly absorbed through the roots which are covered in specially adapted root hair cells, with large surface areas and thin cell walls to aid absorption. It is drawn up the plant through xylem vessels by a pull resulting from the evaporation of water through the stomata on the leaves. This evaporation is called transpiration and the xylem flow resulting is called the transpiration stream. Soluble food substances formed during photosynthesis are transported around the plant in the phloem tubes. This movement of water through the plant in the xylem vessels or phloem tubes is similar to the flow of blood in humans as it transports soluble mineral salts, nutrients and auxins, (plant hormones), from place to place. The evaporation of water from the leaves also removes heat energy from the plant and helps to prevent overheating.

Transpiration pulls water up the plant stem but osmosis is the process whereby water is drawn into or out of cells and tissues. Osmosis is the flow of water by diffusion through a differentially permeable membrane from areas of high water concentration to regions of low water concentration. The diagram below illustrates this:



All plant cell membranes are differentially permeable, which means that they will allow some substances to penetrate them but not others. Water can freely penetrate all membranes. The cellulose cell wall does not act as differentially permeable membrane and will allow most substances that are dissolved in water to freely pass through it.

During photosynthesis, carbon dioxide and water are combined to from glucose sugar. This involves converting light energy into chemical energy stored in the bonds of the sugar molecules. The glucose may be stored in the photosynthesising cell's vacuole as a sugar or converted into starch. The advantage of using the cell vacuole as a storage organ is that the concentration of solutes in the cytoplasm can be kept within levels that allow the cell to function best. Water entering a cell then has to pass through two membranes to reach the solutes in the cell vacuole.

Whether water enters the cell by osmosis or not will depend on the balance between external and internal solute concentrations and the state of the cell. If the solutions on each side of the differentially permeable membrane are equally concentrated then there will be no net movement of water across the membrane. This is called an equilibrium state and the solutions are referred to as being isotonic. A

solution that contains more solute particles than another, and is hence more concentrated, is referred to as being hypertonic. The less concentrated solution is hypotonic. This concentration of solute particles is usually described as a molarity.

A molar solution contains a fixed number of solute particles in a litre of water. The easy way of measuring out this fixed number of particles is to use a mole of particles. One mole contains 6×10^{23} particles, (600,000,000,000,000,000,000,000). Measuring out the Relative Atomic Mass, (R.A.M.), or Relative Molecular Mass, (R.M.M) of the solute in grams and dissolving this in a litre of water will make a 1 molar solution. A 1 molar saline solution, (sodium chloride dissolved in water), would contain ...

A 0.1 molar solution contains ten times fewer solute particles than a 1 molar solution. I will use serial dilution to obtain the molarities for each test.

Even if the solute concentration external to the cell is hypotonic to the vacuole contents the cell will not continue to take in water by osmosis forever. The cellulose cell wall provides a rigid barrier to uncontrolled expansion. A cell that is full of water is called turgid and cannot expand further as the outward pressure on the cell wall is balanced by the inward force of the stretched wall. This wall pressure is called turgor pressure and the internal outward force on the wall is called osmotic pressure. At the other extreme, a cell placed in a solution that is hypertonic to its contents will lose water by osmosis. The cytoplasm will cease to exert a pressure on the cellulose cell wall and the cell, described as flaccid, will lack support. Water loss can continue to such an extent that the cytoplasm, and attached cell membrane, contracts and detaches from the cell wall. A cell in this condition is said to have undergone plasmolysis. This very rarely, if ever happens in nature.

As osmosis is the diffusion of water molecules and as diffusion is the random movement of particles from areas of high concentration to low concentration it might be expected that any factors that speed up or slow down the movement of these particles will affect the rate of osmosis.

Using knowledge of the process of osmosis and with a good understanding of molarity I should be able to determine the solute concentration of the vacuoles in potato tuber cells. As it would be impossible to measure with any degree of accuracy the expansion or contraction of cells on an individual basis I have decided to look at gain or loss of water in terms of increase or decrease in mass. A cell placed in an isotonic solution should show no change whereas one placed in a hypertonic solution will lose mass.

To generate reliable and precise results I will use solutions whose molarity has been determined to two decimal places and measure the mass of my potato samples in grams to the same degree of accuracy. I will use two centimetre long tubes cut from New Potatoes with a cork borer as this length fits easily into a boiling tube and gives me a mass between 1 and 2 grams. My results are therefore likely to be accurate to within ± 0.005 g which represents a mass 100th the size of my sample. This means that I will be 99% confident my measurements are precise.

The solutions I have chosen for my initial tests into cell vacuole solute concentration are:

0.00 M 0.25 M 0.50 M 0.75 M 1.00 M saline solution, and
0.00 M 0.25 M 0.50 M 0.75 M 1.00 M glucose solution.

To eliminate, as far as possible, any errors in my procedure I intend to set up six samples at each concentration. This will hopefully allow me to increase the reliability of my data by using an appropriate number and range of samples.

I intend to use material from the same batch of potatoes, as this will eliminate as far as possible any variation resulting from different treatment or source of supply. New Potatoes should have been freshly harvested and this will reduce any affects that long storage might have on the tubers. I obviously cannot determine whether the potatoes came from the same plant but can be fairly sure they are from the same variety. The potato tubes will be immersed in each solution for 24 hours to ensure that all cells, including those in the central core, have had time to react to the external solute concentration. I

expect to find a solute concentration of between 0.2 M and 0.4 M to be isotonic with my samples based partly on taste but also on the fact that most plants must tolerate a reasonable salt concentration in their surroundings. Both these reasons for my prediction are very subjective and therefore I will run my initial tests to a 1 molar concentration.

Results:

The table below shows the results for potato tubes placed in varying molarities of saline solution for 24 hours.

Molarity	Start mass in grams	End mass in grams	
0.00 M	1.77	2.01	
	1.62	1.89	This result may be inaccurate because the potato tube was jammed in the boiling tube length ways
	1.64	1.81	
	1.44	1.64	
	1.69	1.86	
	1.69	1.86	
0.25 M	1.41	1.02	
	1.71	1.33	
	1.65	1.27	
	1.54	1.19	
	1.62	1.19	
	1.7	1.28	
0.50 M	1.69	1.23	
	1.72	1.25	
	1.63	1.2	
	1.53	1.03	
	1.58	1.08	
	1.59	1.19	
0.75 M	1.59	1.19	
	1.52	1.16	
	1.58	1.13	
	1.61	1.26	
	1.69	1.23	
	1.63	1.18	
1.00 M	1.56	1.21	
	1.54	1.18	
	1.72	1.37	
	1.6	1.25	
	1.62	1.28	
	1.57	1.22	

The table below shows the results for potato tubes placed in varying molarities of glucose solution for 24 hours.

Molarity	Start mass in grams	End mass in grams
0.00 M	1.57	1.59
	1.71	1.67
	1.66	1.73
	1.58	1.65
	1.75	1.77
	1.48	1.48
0.25 M	1.64	1.62
	1.57	1.54
	1.78	1.7
	1.75	1.73
	1.62	1.62
	1.59	1.57
0.50 M	1.69	1.24
	1.75	1.37
	1.64	1.13
	1.73	1.26
	1.81	1.34
	1.83	1.4
0.75 M	1.77	1.23
	1.64	1.07
	1.69	1.2
	1.46	0.97
	1.74	1.12
	1.69	1.07
1.00 M	1.83	1.07
	1.81	1.25
	1.86	1.12
	1.63	0.85
	1.61	0.86
	1.61	0.93

The potato tubes placed in these molarities floated on the surface and this may affect the results.

The glucose results were recorded on a different day from the saline results. The temperature in the laboratory was on average slightly higher.

To investigate whether temperature has any affect on the degree of turgidity or flaccidity shown by the potato tubes a further experiment was carried out. Six tubes were placed in distilled water at 20°C and another six in distilled water at 50°C. Change in mass was recorded every half hour for four hours.

Temp	Change in mass in grams								
	Time in hours								
°C	0	0.5	1	1.5	2	2.5	3	3.5	4
20	1.57	1.65	1.68	1.71	1.74	1.78	1.81	1.84	1.83
	1.41	1.48	1.51	1.53	1.55	1.59	1.61	1.63	1.63
	1.54	1.61	1.72	1.68	1.72	1.75	1.82	1.79	1.81
	1.67	1.75	1.79	1.81	1.84	1.87	1.91	1.93	1.95
	1.61	1.69	1.72	1.76	1.8	1.86	1.89	1.91	1.91
	1.46	1.53	1.56	1.59	1.62	1.66	1.69	1.72	1.71
50	1.55	1.66	1.56	1.47	1.41	1.35	1.33	1.34	1.36
	1.63	1.75	1.63	1.54	1.52	1.47	1.46	1.47	1.47
	1.58	1.69	1.56	1.51	1.46	1.42	1.4	1.42	1.45
	1.58	1.69	1.57	1.49	1.44	1.43	1.43	1.45	1.42
	1.74	1.86	1.76	1.65	1.58	1.57	1.56	1.53	1.56
	1.55	1.66	1.58	1.47	1.4	1.39	1.41	1.39	1.42

If time permits I will narrow my range of molarities down to 0.1 increments around the point where there appears to be least change in mass in an attempt to determine the precise molarity of the potato tuber cell vacuoles.