Assessed practical
Water potential of potato tissue

An investigation into the effect of differing water potentials on the mass or volume of potato tissue, with the final aim to discover the water potential of potato tissue.

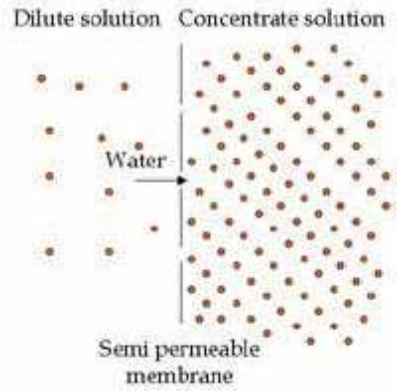
Plan

The purpose of this experiment is to investigate the affect differing water p otentials have on the mass or volume of potato tissue, with the final aim to discover the water potential of potato tissue. Many things need to be looked into when planning for an experiment. For this investigation the most fundamental of which is what wa ter potential is.

Water potential is a numerical representation of "the tendency of a solution to lose water" (*reference Cambridge Advanced Sciences Biology 1 glossary page 258*) and has the symbol ( ). Pure water has the highest water potential of zero. "Water potential is decreased by the addition of solute and increased by the application of pressure." (*Reference Cambridge Biology 1*) All other solutions have a negative water potential which is dependant on how concentrate they are with solute. " In fact when we add solute to water, the water molecules form a shell around each solute molecule. So this decreases the number of free water molecules that are able to exert a pressure on the membrane. Therefore, the water potential decreases" *(Reference ASGURU website)* Therefore the more negative the water potential the more concentrate the solute solution is.

The amount the solute changes the water potential is known as the solute potential ( ). Relative to the investigation the water potential of the potato tissue is dependant on how much starch is present in the potato. The starch is a solute and so will decrease the water potential. Therefore the more starch present the more negative the water potential.

Any water that the potato tissue takes in will be done through the process of osmosis. "Osmosis can be defined as the passage of water molecules through a partially permeable membrane, from a region where they are in higher concentration to a region where they are in a lower concentrati on." *(Reference ASGURU website)*. The movement of water molecules is always from "areas of high potential to areas of low water potential" (*reference* www.winterwren.com) so is down a concentration gradient. This is shown in the picture below. The water would move from the left to the right with the aim of reaching equilibrium.



(Picture referenced from www.rsc_northwest.ac.uk/../newosmosis.html)

Osmosis is only the movement of water molecules; it does not involve any other molecules. "The solute molecules can't diffuse out because the plasma membrane won't let them through." *(Reference ASGURU Website).* The membrane usually

doesn't allow solute molecules through because they are too big. The aim of osmosis is to reach equilibrium. Generally at equilibrium the water potential within the cell is equal to the solute potential of the surrounding environment. This can expressed as: -

When the water molecules move into the cells the pressure builds up. Pressure potential is a positive numerical representation of the pressure within the cells, and has the symbol ( )This can cancel out some of the negativity of the solute potential. This may result in some of the water molecules moving out of the cell whilst trying to reach equilibrium. This means that the new formula for water potential can be written as:-

Water potential = Solute potential + Pressure potential

Different water potentials generally have different affects on plant cells depending on the difference of water potentials between the cell and the surrounding solution. Generally if plant cells are put into a substance with a higher water potential there will be a net movement of water molecules into the cell. This will cause the pressure to build within the cell and causes them to swell and so become turgid. Unlike animal cells they don't burst, this is due to the strong cell wall, which can withstand high pressures. This feature is useful for guard cells of the stomata in leaves so that water or vital substances aren't lost through the stomata on the underside of the leaf. When the cells take in the water molecules the mass and volume increases as they swell and become turgid. The diagram below demonstrates this.

(Picture referenced from www.koning.ecsu.ctstateu.edu/plants_human/osmosis.gif*)*

If plant cells are put into a solution with a lower water potential, there will be a net movement of water molecules out of the cell into the surrounding environment or solution. This causes plasmolysis of the cell, which is where the protoplasm of the cell pulls away from the cell wall. It is said that the cells have plasmolised. This results in the mass and volume of the cell decreasing, as there are less water molecules within the cells. You can see the plasmolysis of a plant cell in the pictures below; they are of red onion cells, which are the type of cells, which were used in one of the preliminary experiments.

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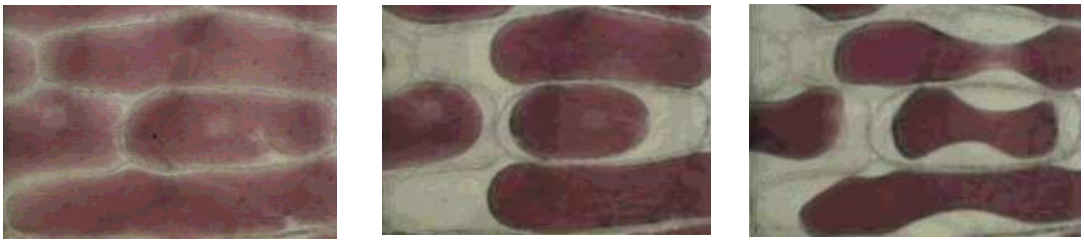

Original cells *fully plasmolised*

(Pictures referenced from www.pgjr.alpine.K12.ut.us/.../Plasmolysis.html)

Also if plant cells are put into a solution of the same water potential there is no net movement of water molecules. There may be some molecules moving into the cell but any movement out of the cell will balance this out. There would be no change in the mass or volume of the cells due to the balancing of the flow of water molecules in and out of the cells. The diagram below shows this.

(Pictures referenced from www.koning.ecsu.ctstateu.edu/plants_human/osmosis.gif*)*

Testing the tissue in solutions with different water potentials, and plotting the results on a graph can measure the water potential of a tissue. Some water potentials would cause the mass or volume of the potato tissue to increase as it takes in the water molecules through osmosis and some of the water potentials will cause the potato tissue to loose mass as it looses water molecules through osmosis out of the cells. Where the curve crosses the X-axis would be the water potential of the potato tissue as there would be no movement of water molecules in or out of the cell. This is what you would expect at equilibrium due to there being no movement of water molecules in or out of the tissue cells, and so the mass or volume will remain the same.

Prediction

Having looked at what water potential is and how it affects the mass or volume of tissues the prediction for this investigation is that as the water potential of the solution increases there will be more movement of water molecules into the tissue cells. This will result in the mass and volume increasing. However for some of the water potentials, the mass or volume will decrease, this will be due to the tissue's water potential being higher than that of the solution. Water molecules will move out of the tissue with the aim to reach equilibrium.
This investigation could consider the affe ct of different water potentials on the mass or volume of the potato tissue. It will be much quicker and easier to measure the

mass of the potato tissue accurately rather than the volume during the investigation, as they can be dried then weighed much qui cker than trying to measure the volume. So the affect that different water potentials will have on the mass of the potato tissue will be considered.
The mass change will be recorded and a graph plotted of the results. This will show what the water potential of the potato tissue is, as this will be where the curve crosses the x-axis. This is where there will be no change in the mass of the potato tissue and so equilibrium.
The water potential of the potato tissue won't be zero as it won't be made of pure water, there will be starch and other solute molecules present. Therefore the water potential will be a negative number. This means that if the solution has a water potential, which is more negative, the water molecules will more out of the tissue cells into the solution. However if the water potential of the solution is less negative there will be a net water movement into the cell.

Variables

The independent variable for this investigation is the water potential of the solution which the potato tissue will be tested in. In this investigation the solution will be sucrose. Diluting it to differing concentrations with water will change the water potential of the sucrose. The chart below shows how the different concentrations will be made. This would produce 10cm of solution, however more will need to be made so as to ensure that there is enough to cover all of the potato tissue completely. 30cm will be made so all of the volumes below need to be multiplied by three.

	0%	0.2%	0.4%	0.6%	0.8%	1%
Volume of sucrose (cm)	0	2	4	6	8	10
Volume of water (cm)	10	8	6	4	2	0

For the investigation to be fair there are a few variables, which need to remain the same. They are: -

- Time- the potato tissue needs to be put in the solution for the same a mount of time. This may be for three minutes. After this time is up the potato chips will be removed from the solution, dried and weighed. Then if the mass has changed again they will be placed back in the solution for a further 2 minutes. This will continue until the masses remain the same for two consecutive weighings.

- Potato tissue source: - the same potato needs to be used for each investigation. This is because different types of potatoes may have different water potentials and so the results wou ld become very inaccurate and unreliable. Also the same potato needs to be used so that the potato tissues are as similar as possible, and of the same age.

- Mass of potatoes: - the mass of the potato tissue needs to be as close to each other as possible. This is because two different samples with differing masses will have different surface areas, which will affect the overall ability of the tissue to take in the water molecules. The potato sample with the larger surface area will take in the water mo lecules quicker and more overall. This is because there is a larger area for them to travel into the tissue. Also the larger potato tissue

will be able to take in more water molecules than a smaller sample as it has a larger volume. This would dramatically affect the overall results and so make them very unreliable and inaccurate. Making the masses of the potato tissues as close to each other as possible will control this.

- Volume of solution: - each of the investigations needs to be performed with the same volume of solution. This is because if the potato tissue is submerged in solutions it will take in or give out more water molecules that if it were just sat in solution. This is because the entire surface is covered and so water molecules can move through all sides rather than just surfaces in contact with solutions. The volume of solutions will be measured out using a syringe once the concentrations have been made using burettes. So as to ensure that the volumes are the same for each investigation.

Within this investigation there are a few uncontrollable variables that need to be considered. They are: -

- Temperature: - each investigation needs to be performed under the same conditions. This is because if one water potential is tested when it is warmer the water molecules will be moving more and so the rate of osmosis increases (Kinetic theory) This may also affect the amount of water molecules that move out of the tissue. Some results achieved may be slightly unreliable due to this because if the water potential is relatively similar and it is colder there may be no movement whereas on a warmer day they may have been movement of water molecules. There will be some fluctuations in the room temperature but this will not have a dramatic affect on the overall results. The results would be affected however if the investigations were performed in extremes. The temperature of the room is uncontrollable but there will only be slight fluctuation in temperature so the results won't be affected drastically.

- Age of potato: - It would be impossible to tell whether a potato is too old for the investigation to work properly so it cannot be controlled. It may be the case that younger potatoes are better to use for the investigation this may be because the younger tissue will be more active than older tissue. Not knowing if the potatoes are all the same age may result in less reliable results. However, as has been stated the age of the tissue source cannot be controlled so it just needs to be assumed that the potatoes are the same age and so that are as active as each other.

Preliminary work

There has been a preliminary experiment performed previous to this investigation, which was an investigation into the plasmolysis of onion epidermis cells in differing concentrations of sucrose. The different concentrations provided different water potentials and so the water potential of the onion cells was discovered. This was where there was 50% plasmolysis of the cells. The onion tissue was put in the different solutions and the removed and viewed under a microscope. The percentage plamolysis was noted and recorded in a table. There are three pictures previously which show the plasmolysis of red onion epidermis cells. The results for this experiment are shown in the table below.

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Concentration of sucrose	Percentage plasmolysis
0	0
0.2	4.55
0.4	36.4
0.6	54.5
0.8	57.1
1.0	68.2

This experiment proves that as the water potential outside of the cell decreases, more water molecules leave the cell through osmosis with the aim to reach equilibrium. Therefore a higher percentage plasmolysis. The results of this experiment can be plotted on a graph and where there is 50% plasmolysis is where the water potential of the onion epidermis cells is equal to that of the surrounding solution. Through doing this it was discovered that the water potential of the onion epidermis cells was around 0.64M as this is where there was 50% plasmolysis. Due to this factor, the investigation with the potato tissue cell s will be performed with differing concentrations of sucrose with the molarity around 0.6. However not all plant cells have the same water potential so the concentrations will still need to be in a wide range so to ensure the correct concentration is cove red in the investigation.

Another preliminary experiment was to prepare six slides with Elodea leaf cells. Two or three drops of differing concentrations of NaCl solutions were placed on one end of the coverslip. By touching a piece of paper towel to th e fluid at the opposite edge of the cover slip a wick is created and so the NaCl solution is drawn across the cells and slide. The cells were examined and a note made of the time taken for the cytoplasm to be no longer pressed against the cell wall, Plasm olysis. The results are shown in the table below.

Concentration of NaCl (%)	Time taken (mins)
Pure water	Swelling of cells
0.45	16.5
0.90	12.5
1.80	7.5
3.60	3.5
7.20	1.5

(Experiment referenced from www.personal.psu.edu/users/t/r/trp2/diffusion.html)

This experiment proved that as the concentration of the NaCl solutions increased the time for total plasmolysis decreased. This means that the time frame for testing the potato tissue needs to be relatively small and at regular intervals. This means that as the water potential of the sucrose solution in the investigation, increases the time taken for the water molecules to move into the potato tissue through osmosis should decrease. This makes it more vital that the tissue samples are tested and their mass recorded at regular intervals.

A preliminary experiment that may need to be performed before starting the actual investigation would be a very simple and quick investigatio n. It would involve cutting three potato chips in one direction (vertically) and then three in the other direction (horizontally). They would be tested in the same molarity of sucrose and the average mass increase recorded. This will help to discover if there is any relationship between the way the chips are cut and their ability to take in the water molecules through osmosis, or to release them. This may be a factor to consider as the way the chips are cut may affect the cell structures within the tiss ue. If they are damaged if

cut in a certain way they may not take in as much water molecules as if they weren't damaged.

Apparatus

Burette this will be used as an accurate way to measure out the volumes of sucrose and water required to make the differi ng water potential solutions. A burette is a much more accurate method rather than using a measuring cylinder or syringe as it has the volumes to one decimal place rather than just to whole numbers.

Sucrose This is used to create the different water po tential solutions. Different volumes of sucrose will be mixed with differing volumes of water so creating different concentrations and therefore different water potentials. As shown in the table previously. Sucrose was used in the preliminary experiment so the table of the conversions of different concentrations of sucrose to their water potentials can be referred to. The table is below. For each investigation 25 cm of the solutions will be used.

Concentration (mol dm)	Water potential
0	0
0.1	-0.26
0.2	-0.54
0.3	-0.82
0.4	-1.12
0.5	-1.45
0.6	-1.70
0.7	-2.17
0.8	-2.58
0.9	-3.01
1.0	-3.40

(Reference from a hand out sheet from a preliminary experiment)

Water this is going to be used to make the different concentrations of sucrose solutions, and so the different water potentials. Pure water will also be used to discover the effect of pure water on the mass of potato tissue.

Weighing scales these are going to be used to measure the mass of the potato chips at each time interval in the i nvestigation. They will weigh the chips very accurately giving the mass correct to two decimal places. The mass is displayed so there is no need for guesswork; this eliminates the chance of anomalous results, which may have resulted from inaccuracy in we ighings. They will need to be dried before weighing them as even one drop of solution could seriously affect the results achieved. The masses of the three chips won't be exactly the same but must be as close to each other as possible, so to avoid anomalo us results occurring.

Potato this is being used, as it is in a ready supply and can be cut to any size and weight easily. Testing it in solutions with differing water potentials can easily discover the water potential of potato tissue.

Cork borer this is going to be used to create cylindrical chips of potato. This provides the largest surface area for the mass of potato as cylinders always give larger surface areas to cuboids. Using a cork borer could also ensure that the chips are cut in the same directions because you would be able to cut them before peeling the

potato and so make sure that all of the chips are cut in the same direction. Compared to if you peeled the potato then started cutting into it with a scalpel, where you could end up cutting the chips in different directions.

Scalpel once the chips have been made with the cork borer they can have the skin cut off using a scalpel. This would then give the maximum surface are for each chip. The scalpel can also be used to cut the chips to t he same length if some are longer than others, or weigh more.

Ruler this will be used to cut the skin off the top and bottom in a straight line.

Stop clock this will be used to time the time intervals that the chips are in the solutions for, accurately. The stop clock makes it much easier because they can be started at zero for each time the chips are put back into the solutions and so ensuring they are in for the correct length of time.

Petri dish the potato chips will be kept in the solution in a pe tri dish with the lid on. This means that you could test more than one water potential at a time. This would be done by labelling the lid with the appropriate water potential and doing the same for the base incase the lids are mixed up. The lids will al so serve the purpose of stopping any of the solutions being lost through evaporation. This is because any water vapour will hit the lid and then reform as a liquid and so drop back down into the solution. This rules out any chance of the results being af fected by evaporation, as the water vapour cannot escape from the petri dish.

Paper towels these will be used to pat dry the chips before they are weighed. This ensures that as much of the solution is removed from the chips so to make the mass measurement as accurate as possible. If they weren't dried before weighing, their mass would also include the weight of any solution as well.

Paper - the petri dishes will be placed on a piece of paper and the letters A, B and C will be written on it above each chip. There will also be another piece of paper so that when the chips are removed from the solution they are put on their letter whilst the others are being weighed. Once they have been weighed they will be placed back in the solution below their appro priate letter. This should reduce the chance of mixing up the chips and therefore the chance of anomalous results occurring should be reduced. This is important because the chips will all be slightly different weights so shouldn't be mixed up.

Method

1. Make appropriate concentrations of sucrose solutions using two burettes, one containing the sucrose (1M) and one for the water.
2. Cut chips out of the potato using a cork borer. Try to make them as close to the same size as each other so that they have about the same mass. Using the cork borer gives the potato tissue a larger surface area to mass ratio and so the investigation should occur quicker.
3. Cut the peel off the chips using a scalpel and ruler so to ensure maximum surface area and so better res ults.
4. Name each chip either A, B or C.
5. Weigh each chip and record it's mass
6. Put the three chips into the pertri dish with the appropriate solution and leave them there for three minutes with the lid on. The lid will stop any solution evaporating off and so affecting the results. This is because any water vapour

that forms will hit the petri dish lid and cool and form a liquid again and drop back into the solution.

7. After the three minutes, remove all three chips and dry them with a paper towel so to remove as much excess solution as possible.
8. Put each chip on its appropriate letter on the other labelled piece of paper so to avoid mixing the chips up.
9. Weigh the mass of each chip and record it in a table under the appropriate letter that corresponds to that chip.
10. Put the chips back into the solution and reweigh every two minutes as in steps 8 and 9, until the masses of all three chips remains the same for two consecutive weighings. This ensures the investigation is complete and so avoids anomalous results. Once there are two readings of the same mass for the chips they have stopped taking in or releasing water molecules and so have reached equilibrium.
11. Record the total mass gain or loss for each chip and then find the average.
12. Repeat this process for all of the concentrations stated previously.

Once all of the average mass losses or gains have been calculated they can be plotted on a graph of water potential against weight loss/gain. Where the curve crosses the x-axis is where there is no mass loss or gain and so the water potential of the cells is equal to that of the surrounding solution. Therefore whatever the water potential is for the sucrose solution, the water potential of the potato tissue will be the same so it can be found in that way.

Risk assessment

- Care needs to be taken when handling glassware so to avoid any breakages and injuries that may occur.
- When using any electrical equipment (i.e. weighing scales) care needs to be taken so to avoid any unnecessary accidents.
- Solutions need to be kept away from electrical sockets and equipment so to avoid the chance of electrocution.
- When filling the burette fill them below eye level to avoid getting solution it eyes.
- Scalpels and cork borers are sharp instruments and so care should al so be taken when using these instruments.

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Bibliography

Type of reference	Use of reference	Title/ Address
Quotes	Quoting in plan	Cambridge Advanced Sciences Biology 1 (glossary and chapter 40
Quotes	Quoting in plan	ASGURU Website (www.bbc.co.uk/education/asguru/)
Images	Diagrams in plan	www.koning.ecsu.ctstateu.edu/plants_human/osmosis.gif
Image	Picture in plan	www.pgjr.alpine.K12.uf.us/…/plasmolysis.html.
Experiment	Preliminary experiment (NaCl)	www.personal.psu.edu/users/t/r/trp2/diffusion.html
Hand out	Sucrose water potential chart	From preliminary experiment of the plasmolysis of onion epidermis cells. Received from teacher
Quotes	Quoting in plan	www.winterwren.com
Image	Diagram in plan	www.rsc_northwest.ac.uk/…/newosmosis.html
Class notes	Research before starting planning period	Notes corresponding to chapter 4 “Cell membranes and transport” in Cambridge Advanced Sciences Biology 1