Osmosis – a special case of diffusion

The particles or molecules in liquids and gases are in constant random motion, allowing them to spread around and fill their environment. They will move from an area where they are highly concentrated to an area wh ere they are less concentrated and this will continue until they are evenly distributed. This process is called diffusion. *(Mitford, H. – Class Notes 07/10/02)*

The cells of all living things are separated from each other by a membrane and rely upon diffusion as a means of transporting some substances in and out of the cell across the membrane. (*Griffin, N.C., A Soaked Potato)* For example, when humans breathe, oxygen molecules enter the lungs and these molecules diffuse across the lung membrane into the blood stream. Diffusion occurs because the oxygen molecules are in a high concentration in the lung and are in a lower concentration in the blood stream. As the diffusing oxygen molecules are quickly carried away by the red blood cells, there is a contin uously high rate of diffusion. Carbon dioxide is expelled in the same way. *(Dawson, B. & Honeysett, I. Revise GCSE Biology)*

Cell membranes are selectively permeable; they allow some things through and not others. *(Purchon, N.D., An account of osmosis for GCSE biology students)* Water molecules are very small and can pass through the cell membrane with relative ease. The concentration of water molecules on either side of the membrane determines the direction in which the water will flow. (*Griffin, N.C., A Soaked Potato)*

For example; if a solute (i.e. sugar) is added to pure water, the sugar molecules attract the water molecules and combine with them, reducing the concentration of water molecules. As the pure water has a higher concentration of water mo lecules, these molecules will diffuse through the membrane into the sugar solution, until the concentration of water molecules is equal on both sides. *(Purchon, N.D., An account of osmosis for GCSE biology students)* Osmosis is the name given to this typ e of diffusion that just involves the movement of water molecules across a cell membrane.

The following experiments were carried out to support the theory of osmosis and attempt to demonstrate osmosis in action.

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<u>The "Egg" experiment</u> *(Mitford, H. – 30/9/02)*

Introduction

As eggs are single whole cells, their use in this experiment should give us an insight into the process of osmosis in the cells of all living organisms.

Method

Two hen eggs were placed in hydrochloric acid to dissolve their shells but keep their membranes intact. They then had the appearance of boiled eggs, but were slightly wrinkled and dry to the touch. The eggs were placed in separate beakers each containing pure water; sugar was added to one of these beakers. They were then left for one week.

Results

	Weight	
	Before	**After**
Pure water (Egg One)	52.52g	68.12g
Sugar (Egg Two)	62.97g	78.94g

Egg One had increased in size by 15.6g, when cut in half it was saturated with water and the yolk was slightly soft. Egg Two had also increased in size by 15.97g and had a similar internal consistency.

Discussion

In this experiment we could have expected Egg One to increase in size as the concentration of water molecules on the outside of the egg was greater than inside. Therefore, the net movement of the water molecules have been into the egg.

The addition of sugar to the water in the beaker for Egg Two should have provided an environment whereby the concentration of water molecules in the beaker would have been lower than that in the egg. The net movement of water molecules should therefore have been away from the egg and it should have reduced in size and be more wrinkled and dry inside. The opposite of this occurred.

There were two possible reasons for this; one, not enough sugar had been used and the water molecules were still in a higher concentration in the beaker. Two, the egg membrane had been damaged when the shell was dissolved. If a cell membrane is damaged or destroyed then the cell no longer has control of substances entering in or out of it. The water molecules in this case would have flowed freely into the egg.

<u>The "Potato" experiment – conducted at home</u>(*Griffin, N.C., <u>A Soaked Potato</u>*)

Introduction

Potatoes are used in this experiment as they have a very high concentration of water molecules. Therefore, adding potato to pure water should not affect it, as the concentrations on both sides of the membrane would be the same. Sugar and salt added to water sho uld reduce its water molecule concentration, which will draw water away from the potato, affecting its size.

Method

I filled three drinking glasses with approx. 100ml of pure water. I added four tablespoons of salt to the first glass, four tablespoons o f sugar to the second glass, nothing else was added to the third.

I then placed an equal size "chip" of potato, which had been measured, in each glass; the texture of the potato was crisp, firm and wet to the touch. The potato was then left for two days.

Results

	Size of potato "chip"	
	Before	***After***
Salt & water	32mmx14mm	26mmx11mm
Sugar & water	32mmx14mm	27mmx11mm
Pure water	32mmx14mm	33mmx16mm

The potato in pure water had increased slightly in size and its texture remained unaltered. The potato in both the sugar and salt solutions had decreased in size and became spongy and dry to the touch.

Discussion

The potato I used for this experiment had been dug from my garden about two months ago and due to its age, probably had less water in it than a younger potato. The potato could also have had some substance, perhaps from the soil, dissolved in its water, which could have lowered it's water molecule concentration. This might explain why there was a slight uptake of water in the potato in pure water, when you could have expected the potato to stay the same size.

The potato in the sugar and salt solutions gave the expected results. There would have been a very low concentration of water molecules in the solutions, which drew out the water in the potato reducing them substantially in size. Once they were dried with a paper towel, the potato also felt very dry and warm, indicating there wasn't much, if any water left in it.

Both experiments demonstrated osmosis and the conditions in which it occurs. There was clear evidence that the introduction of other substances into pure water can lower the concentration of water molecules, which would affect the direction in which the pure water molecules would flow across a membrane.

We also saw that damage to the cell membrane would prevent osmosis from happening, as the membrane would no longer be able to control the flow of water molecules and water would enter the cell by diffusion until it reached capacity.

The action of osmosis has quite different consequences in animal cells verses plant cells. Animal cells, if exposed to a solution with a high concentration of water molecules, called a “hypotonic” solution, would eventually swell up and burst, as the net movement of water molecules would be into the cell. If the animal cell were placed in a solution with a low concentration of water molecules, called a hypertonic” solution, water would move away from the cell and it would shrivel up and eventually die. *(Messrs, Robert, Reiss & Manger, Advanced Biology) (Mitford, H. – Class Notes 07/10/02) (Purchon, N.D., An account of osmosis for GCSE biology students).*

These actions have major implications for the human body. For instance, if we were to consume too much water, our cells would become saturated; this would increase pressure in the brain and eventually cause death. Similarly, osmosis is the reason you cannot drink salt water if stranded at sea! The low concentration of water molecules in seawater would draw water from the cells in your body and you would eventually die from dehydration. *(Mitford, H. – Class Notes 07/10/02) (Brains, M. How does reverse osmosis work to purify or filter water?) (Purchon, N.D., An account of osmosis for GCSE biology students).*

Plant cells have a cell membrane, which is surrounded by a strong cell wall, which is not selective and will allow anything through easily. If a plant cell is placed in a “hypotonic” solution, the cell will take on water and the membrane will expand and push against the cell wall. It will not burst as the cell wall remains intact holding the contents of the plant cell in. Once the cell wall has been stretched to capacity the flow of water into the plant cell will stop. If the plant is placed in a “hypertonic” solution, the water will be drawn out of the cell, and the contents of the plant cell and its membrane will shrink away from the cell wall. *(Messrs, Robert, Reiss & Manger, Advanced Biology) (Mitford, H. – Class Notes 14/10/02)*

This is why, when a plant has regular water, its leaves are firm and stand up, if the plant is deprived of water, it droops and the leaves shrivel up.

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Osmosis is applied to many day-to-day industrial processes and products. For example; water purification and desalination. Extremely fine filters are used as membranes, with contaminated water on one side and pure water on the other. Usually, the net movement of water molecules would be from the pure water to the contaminated water. However, this flow can be stopped and reversed by applying a pressure on the contaminated water side, which then allows for the flow of pure water molecules across the membrane away from the contamination or salt. This process is called reverse osmosis. *(Lachish, U., Osmosis, Reverse Osmosis and Osmotic Pressure, what are they?) (Brains, M. How does reverse osmosis work to purify or filter water?)*

Another example of osmosis is in food preservation. Bacterial growth is prevented in foods which are packaged in salt or sugar. This is because these solutes draw the water out of the bacterial cells, which prevents their growth and therefore, preserves the food. *(Diffusion, Osmosis and Cell Membranes, Dept. of Biochemistry, University of Arizona)*

A well-known product also uses the osmosis principal. Gore-Tex is a man-made thin porous membrane that is bonded to fabrics to make them waterproof but breathable. There are nine billion pores per square inch in the Gore-Tex membrane, which make it too small for even water molecules to cross it, therefore, keeping you dry. However, water vapour molecules are small enough to cross the membrane so, as you perspire, these molecules will move away from your body across the Gore-Tex membrane to where they are in a low concentration (outside your clothes). *(Krash, P. Dead Runners Society) (Brains, M. How does reverse osmosis work to purify or filter water?)*

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