Investigating the effect of changing surface area-to-volume ratio on diffusion

Transcript

The cell surface membrane is an effective barrier. However, the exchange of substances between the cell and its external environment is vitally important.

The membrane is only permeable to molecules via specific mechanisms: diffusion, facilitated diffusion, osmosis, active transport and bulk transport.

Simple diffusion is the net movement of particles, usually ions or molecules, from a region of high concentration to a region of lower concentration until an equilibrium is reached.

The structure of the cell membrane restricts which particles can move between the cell and its external environment by simple diffusion. Only particles which are hydrophobic or very small can move directly across the phospholipids arranged in a bilayer, which comprises the majority of the cell membrane.

This investigation shows how varying the surface area-to-volume ratio of a cell affects diffusion of a small molecule.

It is important to understand that as an object, such as a cell, grows, its surface area increases and its volume increases. However, if we divide surface area by volume we can find the surface area-to-volume ratio, which reduces. Therefore, large organisms have smaller surface area-to-volume ratios than small organisms. This has important implications for the rate of diffusion between a cell and its external environment. It also means that there is a limit to the size that cells can grow. This is because after a certain size, the rate of diffusion becomes too low for the cell to function.

To investigate the effect of changing surface area-to-volume ratio on the rate of exchange by diffusion, model cells of different sizes can be made by cutting cubes of agar of different sizes out of a block of agar.

Agar is a jelly-like solid substance that can be stained using cresol red solution. This investigation relies on the fact that when dilute hydrochloric acid is added to cresol red solution, a chemical reaction occurs which causes the red colour to become orange.

Making sure that the scalpel blade is vertical, any curved edges are removed from the block to form a rectangular block. From this block, five cubes are cut with a range of dimensions. Care is taken to precisely measure the lengths to ensure they are of accurate size.

These cubes will represent models of cells having different sizes in this investigation. The largest cube has the smallest surface area-to-volume ratio.

The surface area-to-volume ratio of the cubes can be calculated before the experiment begins, or during the experiment. The table shows the surface area to volume ratio for each cube. These figures have been converted into decimal numbers, which will be easier to plot on a graph. For example, for the largest cube, the ratio of 1.01-to-2.19 is expressed as 0.46.

The agar cubes are all placed into a flat glass dish. Dilute hydrochloric acid is also poured into the dish until it is half full. The stopclock is started.

It's important sure that the cubes do not touch each other. A glass rod can be used to move them around slightly inside the acid.

As the acid diffuses into the agar cubes, it reacts with the cresol red dye, which turns from red to orange. The time it takes for each cube to completely become orange is recorded. The larger the cube, the longer it will take for the red colour to disappear.

The collected data can be used to plot a graph of surface area-to-volume ratio against the time taken for the agar cube to turn completely orange.

It can be clearly seen that a decrease in surface area-to-volume ratio is associated with a reduction in the rate of diffusion into the model cell. The plotted line has a negative exponential relationship.

Most cells have a surface area-to-volume ratio that is large enough to enable to them to gain and lose materials by simple diffusion across their cell surface membrane. This also includes single-celled organisms, such as Plasmodium, the parasite that causes malaria.

This experiment provides one possible explanation for the evolution of specialised transport systems in larger, multicellular organisms to help exchange nutrients and waste.