DA 1

# Limitations to Cell Size

When an object (e.g. a cell) is small it has a large surface area in comparison to its volume. In this case diffusion will be an effective way to transport materials (e.g. gases) into the cell. As an object becomes larger, its surface area relative to its volume becomes less. Diffusion is no longer an effective way to transport materials to the inside. For this reason, there is a physical limit for the size of a cell, with the effectiveness of diffusion being the controlling factor.

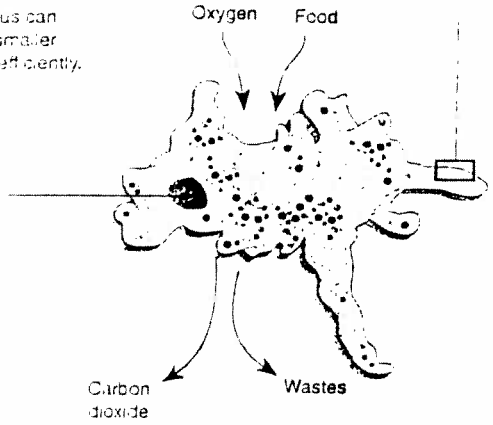
## How Diffusion Affects Animals of Different Size

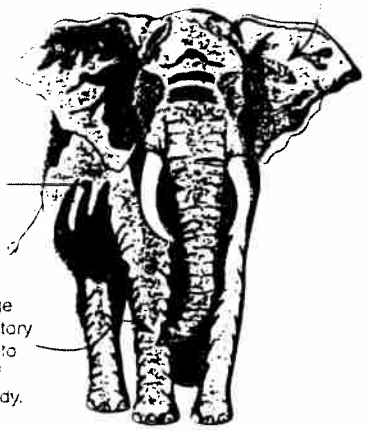
Respiratory gases and some other substances are exchanged with the surroundings by diffusion or active transport across the cell membrane.

The **plasma membrane** that surrounds every cell functions as a selective barrier that regulates the cell's chemical composition. For each square micrometre of membrane, only so much of a particular substance can cross per second.

The surface area of an elephant is increased, for radiating body heat, by large flat ears.

The nucleus can control a smaller cell more efficiently.



Respiratory gases cannot reach body tissues by diffusion.

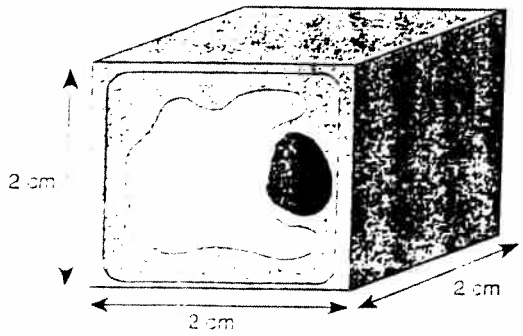
A specialised gas exchange surface (lungs) and circulatory (blood) system is required to speed up the movement of substances through the body.

**Amoeba:** The small size of the single-celled amoeba provides a large surface area compared to its volume. This is adequate for many materials to be moved into and out of the cell by diffusion or active transport.

**Multicellular Organisms:** To overcome the problems of small cell size, plants and animals became multicellular. They provide a small surface area compared to their volume but have evolved various adaptive features to improve their effective surface area.

## Why Smaller is Better For Diffusion

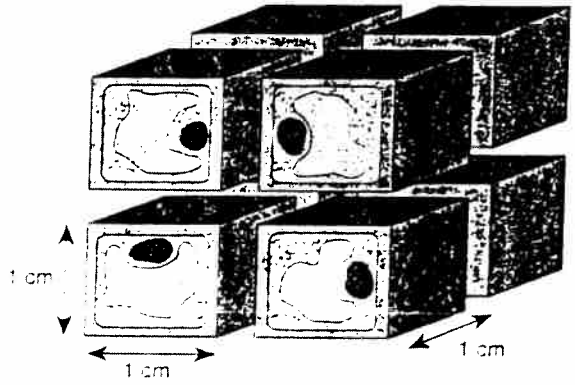
### One Large Cube




Volume: = 8 $cm^3$

Surface Area: = 24 $cm^2$

### Eight Small Cubes




Volume: = 8 $cm^3$ for 8 cubes

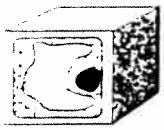
Surface Area: = 6 $cm^2$ for 1 cube

= 48 $cm^2$ for 8 cubes

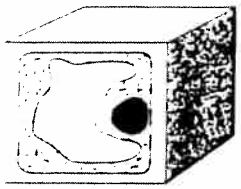
The eight small cells and the single large cell have the same total volume, but their surface areas are different. The small cells together have twice the total surface area of the large cell, because there are more exposed (inner) surfaces. Real organisms have complex shapes, but the same principles apply.

The surface-area volume relationship has important implications for processes involving transport into and out of cells across membranes. For activities such as gas exchange, the surface area available for diffusion is a major factor limiting the rate at which oxygen can be supplied to tissues.

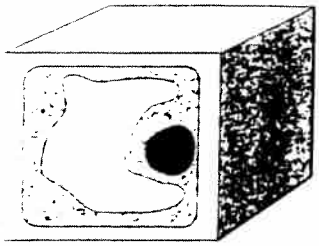
The diagram below shows four imaginary cells of different sizes (cells do not actually grow to this size, their large size is for the sake of the exercise). They range from a small 2cm cube to a larger 5cm cube. This exercise investigates the effect of cell size on the efficiency of diffusion.



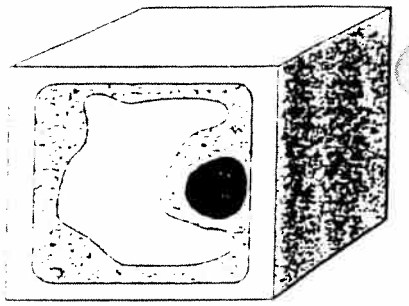
**2 cm cube**



**3 cm cube**



**4 cm cube**



**5 cm cube**

1. Calculate the **volume, surface area** and the **ratio of surface area to volume** for each of the four cubes above (the first has been done for you). When completing the table below, show your calculations.

| Cube Size | Surface Area | Volume | Surface Area / Volume Ratio |
|---|---|---|---|
| 2 cm cube | $2 \times 2 \times 6 = 24\ cm^2$ (2cm x 2cm x 6 sides) | $2 \times 2 \times 2 = 8\ cm^3$ (height x width x depth) | 24 to 8 = 3 to 1 |
| 3 cm cube | | | |
| 4 cm cube | | | |
| 5 cm cube | | | |

2. Create a graph, plotting the surface area against the volume of each cube, on the grid on the right. Draw a line connecting the points and label axes and units.

3. State which increases the fastest with increasing size - the **volume** or **surface area**.

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4. Explain what happens to the ratio of surface area to volume with increasing size.

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5. Diffusion of substances into and out of a cell occurs across the cell surface. Describe how increasing the size of a cell will affect the ability of diffusion to transport materials into and out of a cell.

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