How does the size of a cell affect diffusion?

Background

Nutrients and oxygen need to diffuse through the cell membrane and into the cells, whilst wastes must diffuse out before their concentrations rise to toxic levels within the cell.

Most cells are no more than 1mm in diameter because small cells enable nutrients and oxygen to diffuse into the cell quickly and allow waste to diffuse out of the cell quickly. If the cells were any bigger than this then it would take too long for the nutrients and oxygen to diffuse into the cell so the cell would probably not survive.

This investigation will examine the effect of increasing size on diffusion into agar blocks. Agar is permeable and so it can be used to model the diffusion of materials into a cell. Cresol red is a pH indicator: it is red in alkali and yellow in acid. The time taken for the colour to change completely from red to yellow in agar cubes can be used as a measure of how long it takes an acid to diffuse to the centre of these blocks.

Materials and equipment

- 5 test tubes and rack
- non-nutrient agar block impregnated with cresol red

- dilute hydrochloric acid
- stop watch
- scalpel or razor blade
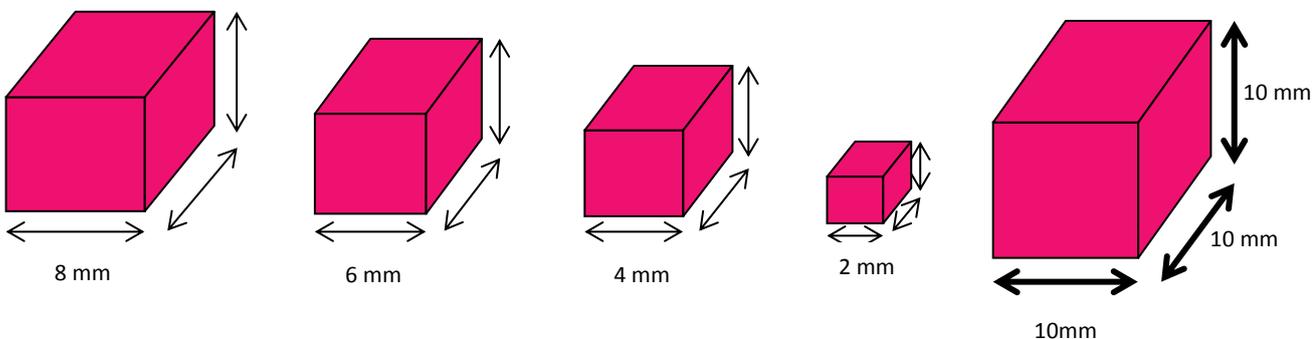- white tile or Petri dish

- 30 cm ruler
- measuring cylinder

Method

1. You are provided with a block of agar which has been impregnated with cresol red.
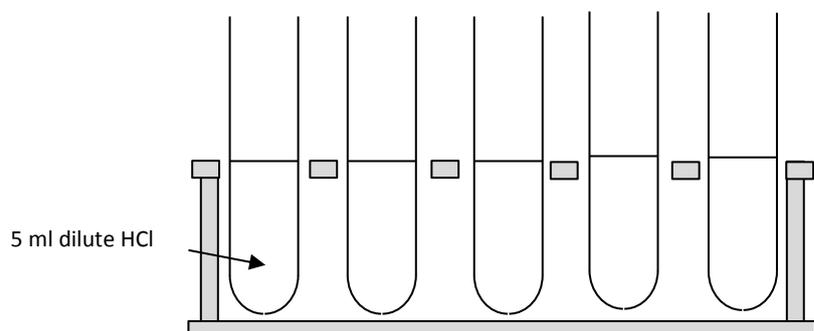
   Place the agar block on a white tile or Petri dish lid and using a scalpel or razor blade cut a cube of agar of side 10mm
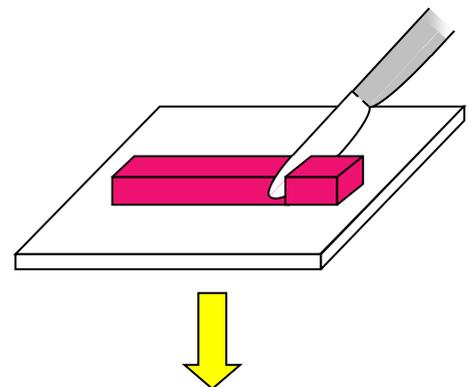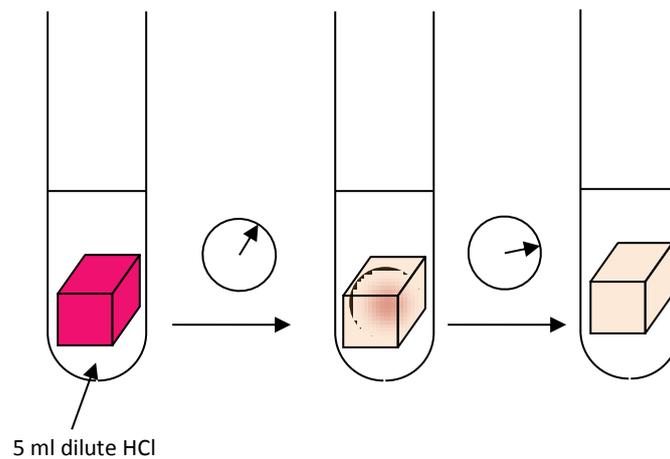
2. Cut 4 further cubes of side 8, 6, 4 and 2 mm respectively.

8 mm   6 mm   4 mm   2 mm   10mm

10 mm

10 mm

3. Stand five test tubes in a rack and add 5 ml dilute hydrochloric acid to each

5 ml dilute HCl

4. Drop your 10mm agar blocks into a test tube and start your stop watch. Time how long it takes for you block to turn *completely* yellow.

5 ml dilute HCl

Repeat steps 2 to 4 for each of your agar blocks

Tasks

1. Complete the table below:
    -   Surface area of a cube = $6x^2$ where x is the length of one side of the cube
    -   Volume of a cube = x^3
    -   Surface area:Volume Ratio = surface area ÷ volume

Cube dimensions (mm)	10x10x10	8x8x8	6x6x6	4x4x4	2x2x2
Total Surface Area (mm^2)					
Total Volume (mm^3)					
Surface Area: Volume Ratio (mm^{-1})					
Time taken for acid to reach centre of agar block (s)					
Rate of penetration, 1000/t, (s^{-1})					

The time taken for the acid to diffuse to the centre of the cube is the time taken for all the cresol red indicator to turn from red to yellow.

Rate of penetration = 1000 ÷ time taken for acid to diffuse to centre of the cube

2. Plot a graph of time taken for acid to reach the centre of the block (y axis) against length of one side of the block (x axis)
3. Describe how size affects how long it takes for materials to diffuse to the centre of the cube of agar.
4. Plot a graph of rate of penetration (y axis) against surface area:volume ratio of the block (x axis) – to plot this graph you will need to work out surface area:volume ratio as a *decimal*.
5. Describe the relationship between surface area:volume ratio and rate of penetration