Change size, compare penetration

Question: how does cube size affect the fraction of agar reached after the same exposure time? Cube size changes both SA:V and the distance to the centre.

1. A FIXED-TIME INVESTIGATION

A. CUT AND MEASURE

Use teacher-prepared alkaline agar with phenolphthalein. Cut cubes of different side lengths, such as 1, 2 and 3 cm. Record actual dimensions.

B. EXPOSE ALL FACES

Fully immerse separated cubes in dilute acid. Keep access to all faces comparable. Use the same exposure time and start timing as each cube enters.

C. REVEAL THE CORE

Remove at the set time, rinse promptly and cut through the centre on a tile. Measure the remaining pink core before further colour change.

D. REPEAT AND COMPARE

Use independent repeat cubes of each size. Calculate the percentage volume changed for each cube, then compare the means and variation.

2. CONTROL EVERYTHING EXCEPT CUBE SIZE

Keep agar composition, acid concentration, temperature, mixing and immersion time constant. Use equal, sufficiently large acid volumes so acid is not appreciably depleted. Keep the shape cubic. Larger cubes must not rest against or shield smaller ones.

3. IDENTIFY WHAT IS BEING MEASURED

Independent variable: cube side length and its calculated SA:V. Dependent variable: percentage volume that changes colour after a fixed time. Acid entry neutralises the alkali, turning the indicator from pink to colourless.

Safety: wear eye protection; use teacher-approved dilute solutions and a cutting tile. Handle blades carefully and do not eat laboratory materials.

Practical method: Practical Biology, Effect of size on uptake by diffusion.

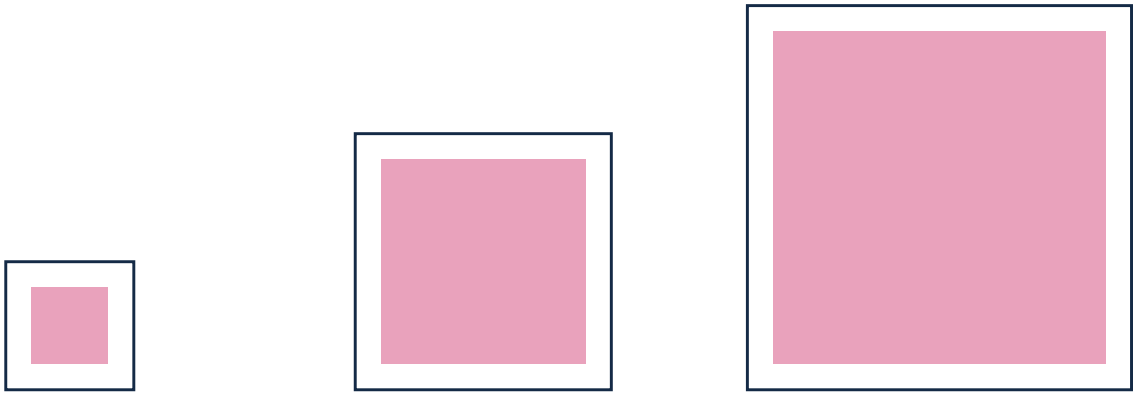
Comparing penetration: Exploratorium, Agar Cell Diffusion.

Scope: Cambridge Biology 9700 syllabus, section 4.2, outcome 4, p. 21.

Same depth, different proportions

Illustrative model, not measured results: assume acid produces a colourless layer 0.2 cm deep from every face after the same time in each cube.

1. CUT-FACE VIEWS AT THE SAME SCALE



1 cm cube **2 cm cube** **3 cm cube**

White = colourless outer region; pink = remaining alkaline core.

2. COMPARE VOLUMES, NOT JUST LENGTHS

SIDE / cm	SA:V	CORE SIDE / cm	VOLUME CHANGED
1	6:1	0.6	78.4%
2	3:1	1.6	48.8%
3	2:1	2.6	34.9%

SA:V uses surface in cm² and volume in cm³. Percentages use whole-cube volumes.

3. SMALLER CUBES HAVE A LARGER FRACTION REACHED

The colourless rim has the same depth in these drawings, but occupies more of the smaller cube. Its centre is also nearer a surface. A larger percentage penetrated does not, by itself, show that particles move faster through the smaller block.

These percentages describe a three-dimensional shell. Squaring the cut-face dimensions gives area, not volume, and produces the wrong percentage.

Percentage-volume approach: Exploratorium, Agar Cell Diffusion.
Size and SA:V context: OpenStax Biology 2e, section 4.2, Cell Size.

Scope: Cambridge Biology 9700 syllabus, section 4.2, outcome 4, p. 21.

Calculate, then evaluate

Use consistent length units. The uncoloured region is a three-dimensional outer shell, so subtract the pink core volume from the original cube volume.

1. WORKED EXAMPLE: SIDE 2.0 cm, DEPTH 0.2 cm

Core side = 2.0 - (2 × 0.2) = 1.6 cm

Original volume = 2.0^3 = 8.000 cm^3

Pink core volume = 1.6^3 = 4.096 cm^3

Colourless volume = 8.000 - 4.096 = 3.904 cm^3

$$\%\ \text{changed} = \frac{3.904}{8.000} \times 100 = 48.8\%$$

General rule: % changed = [(original volume - core volume) ÷ original volume] × 100.

2. DEAL WITH REAL, UNEVEN RESULTS

Measure the core length, width and height if it is not cubic; multiply all three to find its volume. Repeat with more cubes, report a mean and spread, and check unexpected results. Use a consistent cutting plane, ruler and colour-boundary judgement.

3. AN ALTERNATIVE ENDPOINT: TIME TO THE CENTRE

Instead of fixing exposure time, compare the time until no pink core remains. Smaller cubes usually reach this endpoint sooner. Use separate replicate cubes for destructive checks at successive times; do not return a cut cube, because cutting creates new exposed surfaces.

Model limit: agar has no living membrane, transport proteins or metabolism. The indicator records diffusion plus a chemical reaction. The model illustrates size constraints on exchange, but is not a direct measurement of transport in a living cell.

Measurement and endpoint methods: Practical Biology, Effect of size on uptake by diffusion.
Biological size constraints: OpenStax Biology 2e, section 4.2, Cell Size.

Scope: Cambridge Biology 9700 syllabus, section 4.2, outcome 4, p. 21.