ANSWER KEY.

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Same Volume, Different Shapes

Biology | ANSWER KEY

Sample answers and data. Accept answers that match the group's own data and reasoning.

Draft lab. This lab has not been tested in a classroom yet. Your teacher may change some steps, times or amounts.

The Puzzle

Red blood cells are flat disks. Nerve cells are long and thin. Intestines are lined with tiny finger-like villi. Why do so many cells and organs have flat or skinny shapes? You will model three "cells" with the **same volume** but different shapes, made of gelatin with red cabbage juice. The juice is a pH indicator: it is blue-green in the gelatin and turns pink where vinegar diffuses in.

Question

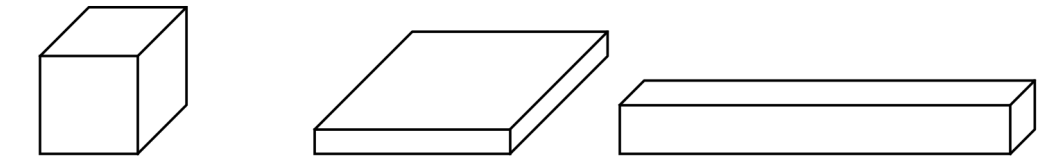
If three cells have the same volume, which shape lets material diffuse into the most of the cell in the same amount of time?

Safety

- Wear goggles. Vinegar stings eyes.
- Do not eat the gelatin. Use the plastic knife only on the cutting board.

Materials (per group)

- Three gelatin blocks: a cube (2 × 2 × 2 cm), a slab (4 × 4 × 0.5 cm), and a rod (8 × 1 × 1 cm)
- Shallow dish with about 150 mL of white vinegar
- Plastic spoon, plastic knife, cutting board, ruler (mm), paper towels, timer



cube 2 × 2 × 2 cm | slab 4 × 4 × 0.5 cm | rod 8 × 1 × 1 cm

Three model cells. Each has a volume of 8 cm^3.

Before the Lab

1. Complete the table below for each shape before you start. Then predict which shape will turn the most pink in 10 minutes.

Prediction: the slab, because it has the most surface area for the same volume and no part is far from the surface.

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Table 1. Shape measurements

Shape	Length × width × height (cm)	Volume (cm^3)	Surface area (cm^2)	SA:V ratio
Cube	2 × 2 × 2	**8**	**24**	**3.0**
Slab	4 × 4 × 0.5	**8**	**40**	**5.0**
Rod	8 × 1 × 1	**8**	**34**	**4.25**

Surface area of a box = 2 × (L × W + L × H + W × H)

Procedure

1. Gently place all three blocks in the vinegar at the same time. Start the timer.
2. After 10 minutes, lift each block out with the spoon and blot it dry.
3. Cut each block in half across its middle. Look at the cut face.
4. Measure the depth of the pink layer (from the outside edge to where the blue-green starts), in cm. Measure in two places and average.
5. Calculate the percent of each block that turned pink using the formula below the data table.

Data

Table 2. Diffusion results

Shape	Pink depth, d (cm)	Uncolored core volume (cm^3)	Percent colored
Cube	**0.2**	**1.6 × 1.6 × 1.6 = 4.10**	**49%**
Slab	**0.2**	**3.6 × 3.6 × 0.1 = 1.30**	**84%**
Rod	**0.2**	**7.6 × 0.6 × 0.6 = 2.74**	**66%**

Uncolored core = (L - 2d) × (W - 2d) × (H - 2d). Percent colored = (8 - core) ÷ 8 × 100

Analysis

2. Compare the pink depth in the three shapes. Did the vinegar travel farther into one shape than another?

   No. The pink depth was about the same (0.2 cm) in all three shapes. Vinegar diffuses into gelatin at the same rate regardless of shape.

3. If the depth was about the same, why did the shapes end up with different percents colored?

   Shapes with more surface area for their volume have less of their volume far from the surface. In the slab, almost every point is within 0.25 cm of the surface; the cube's center is 1 cm deep.

4. Rank the shapes by SA:V ratio and by percent colored. What pattern do you see?

   SA:V: slab (5.0) > rod (4.25) > cube (3.0). Percent colored: slab (84%) > rod (66%) > cube (49%). Higher SA:V, more of the cell reached (sample).

5. Which shape would be fully pink first? Explain using the distance from the center to the nearest surface.

   The slab. Its center is only 0.25 cm from a surface, compared with 0.5 cm for the rod and 1 cm for the cube.

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6. A cell gets oxygen and nutrients by diffusion across its membrane. Use this lab to explain why red blood cells are flat and why intestines have villi.

A flat shape and villi add surface area without adding much volume. More membrane area for the volume lets oxygen and nutrients diffuse into all of the cell or tissue quickly.

7. Claim, evidence, reasoning: Is a larger surface area to volume ratio better for a cell that depends on diffusion?

Claim

Yes. A higher SA:V ratio lets diffusion reach more of the cell's volume in the same time.

Evidence

With the same 8 cm^3 volume, the slab (SA:V 5.0) was 84% colored after 10 minutes, but the cube (SA:V 3.0) was only 49% colored (sample).

Reasoning

Diffusion travels about the same distance per minute in every direction. When more of the volume is close to the surface, more of it is reached quickly.

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