Why Don't Cells Grow Larger? A Lab Exercise

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This exercise provides students with an insight into "why cells don't grow larger" through an analysis of the ratio of surface area to volume as it relates to cell division. It also introduces the use of a model as an aid in investigations. This exercise has been modified from one previously developed by the Biological Sciences Curriculum Study (BSCS). It simplifies the BSCS exercise and organizes data so that students can better understand why a cell cannot take in enough nutrients to sustain continued growth.

In this modified exercise, students use four cylinders of agar gel with a pH indicator added. Each cylinder is a different size and represents a model of a cell. Each "cell" is then "fed" an acid for a measured time. The volume of the portion of the cylinder which changes color represents that part of the cell which has been fed, while the area which retains its color simulates the area which does not receive food.

Students can use this technique to determine the effect of surface area to volume ratio on cell growth. By calculating surface area and volume for both "fed" and "unfed" portions of each "cell," the student can determine that as the cell models increase in size, both surface area and volume increase, but the ratio of surface area to volume decreases.

Discussion can then lead students to understand that as a cell grows larger, there is less surface area available to absorb food for a given volume. The living cells' solution to this problem is to divide, thereby producing more surface area and a greater surface area to volume ratio. Thus, the exercise demonstrates both visually and mathematically the need for cells to divide after a period of growth.

Procedures

Cell models are made from a 2% agar solution with an indicator (e.g., Brom cresol green) added. Agar is poured into three test tubes of different sizes (e.g., 15mm, 18mm, and 25mm) to about three-quarters full. The tubes are stoppered tightly and inverted so that the agar solidifies at the stoppered end (fig. 1).

To remove the solidified cylinders, heat the bottom of each tube in boiling water. This will cause the air to expand and push the agar out of the tube far enough that it can be removed (fig. 2).

Cut the two largest diameter cylinders to a length of 3cm (cell models #1 and #2), and the smallest diameter cylinder to lengths of 2cm and 1cm (cell models #3 and #4, respectively) (fig. 3). Excess agar can be melted and recycled. Record cell identifying number, diameter, and length in the "Before Feeding" section of table 1. Place the cell models in a finger bowl and cover with a 0.3N solution of sulfuric acid as a simulated cell nutrient (fig. 4).

"Feed" the cells for about eight minutes, or to the point where the smallest one loses most of its color (fig. 5). (Blue vanishes in the case of Brom cresol green.) Measure the diameter and length of the remaining colored blue cylinder representing the unfed portion of each "cell." Place measurements in the "After Feeding" section of table 1. The percentage of the cell that was "fed" can be computed using calculators. Students often need help to determine a sequence that will require the minimum number of computations. Following this analysis the students can discuss:

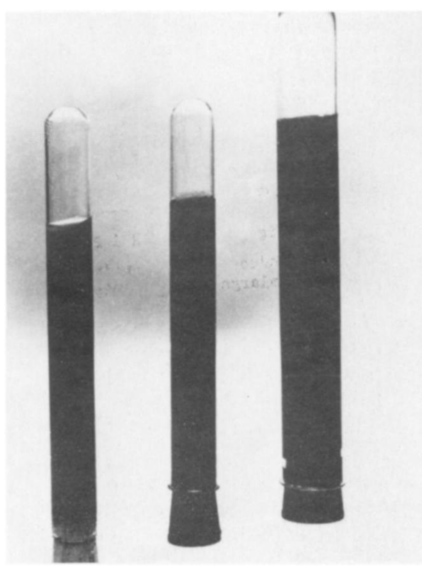

FIGURE 1. Three test tubes of different lengths are filled to three-quarters full, stoppered tightly, and inverted.

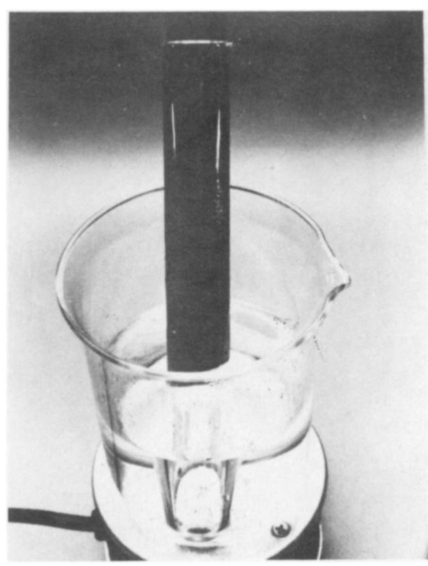

FIGURE 2. Removing the solidified cylinders.

TABLE 1. Determining the Effect of Surface Area to Volume Ratio on Cell Growth.

	Colored Portion Before "Feeding"			Colored Portion After "Feeding"			
Cell	*Diameter*	*Length*	*Volume*	*Diameter*	*Length*	*Volume*	*Percent of Cell "Fed"*

$v=r^2l$ Percent of cell fed $= \frac{v_o - v_u}{v_o} \times 100 =$

Where v_o = original volume of cell
v_u = volume of unfed portion

- If the cylinders were living cells and the sulfuric acid a vital nutrient, which cell would be able to supply the greatest proportion of its volume with this nutrient?
- Which cell might be in danger of starving because it could not take in enough nutrients?

The ratio of surface area to volume can be investigated with the same data. Using table 1 and the blue "unfed" portions of the cylinders, measurements for eight different "cells" from smallest to largest can be recorded in table 2. The surface area and ratio of surface area to volume can then be calculated, and the following questions discussed:

- As cell volume increases, how does the surface area change?
- What happens to the surface area to volume ratio as the cell gets larger?
- How does that portion of the cell that receives nutrients change as the size increases?

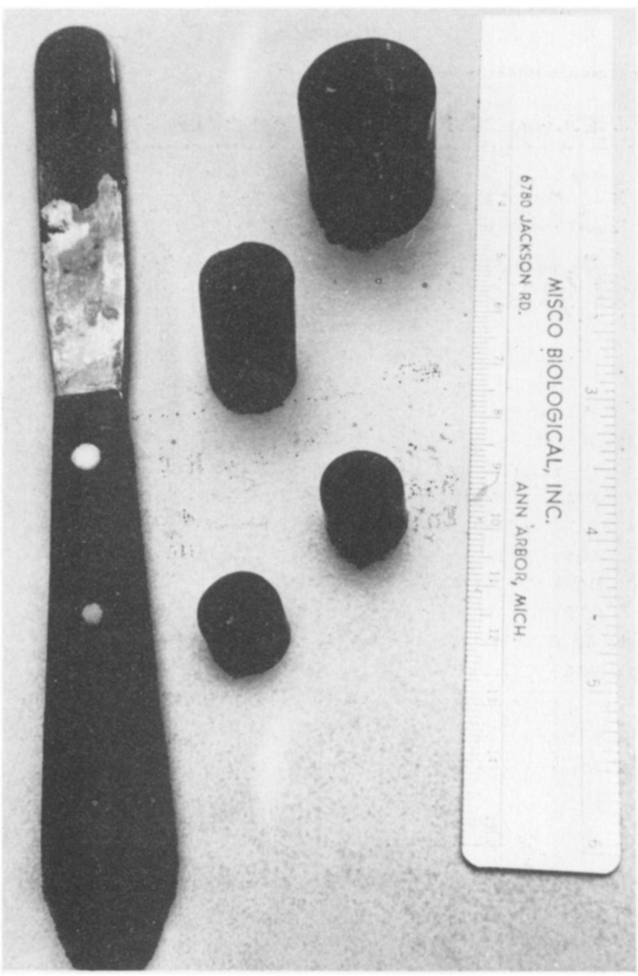

FIGURE 3. The cylinders are cut into varying lengths.

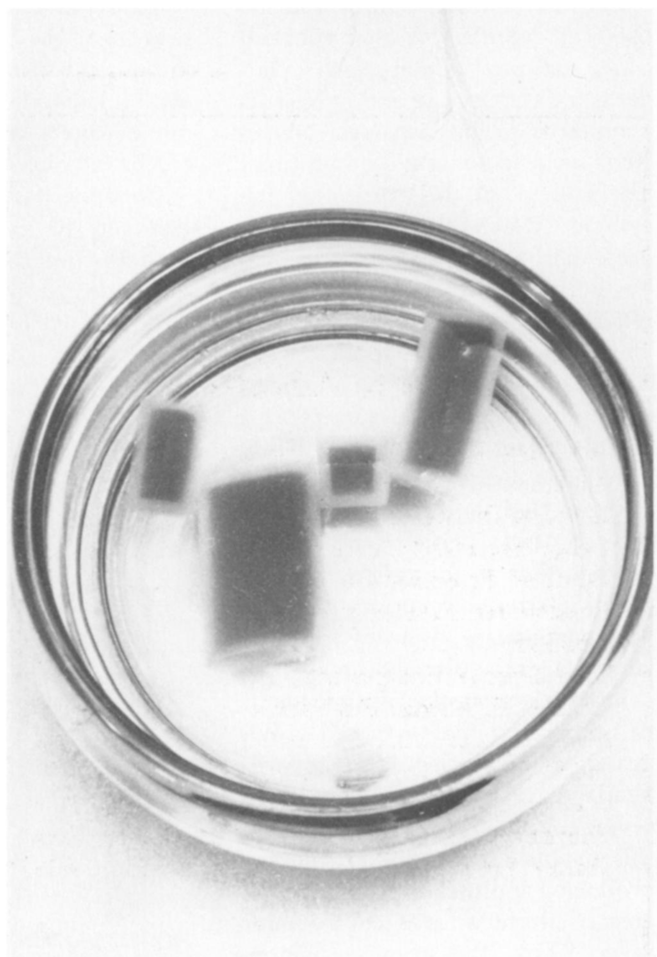

FIGURE 4. Cell models are placed in a bowl with sulfuric acid.

- If a cell divides in half, how does the volume of each new cell compare with that of the original cell?
- If a cell divides in half, how does the surface area of each new cell compare with that of the original cell?

Reference

BIOLOGICAL SCIENCES CURRICULUM STUDY. 1973. Investigation 13-A. *Molecules to man (Blue version)*. Boston: Houghton Mifflin Co.

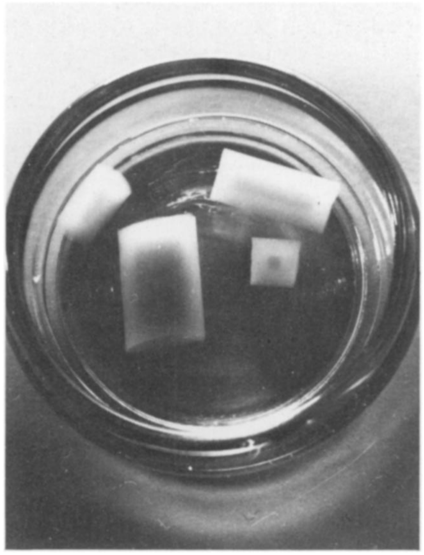

FIGURE 5. After "feeding," the smallest cylinder portion has lost most of its color.

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method. *American Biology Teacher* 42:235.

Helpful student references

Projects of the Finalists, Abstracts of the International Science and Engineering Fairs. Available from: Science Service, Inc., 1719 N Street, N.W., Washington, D.C. 20036.

Abstracts of the Junior Science and Humanities Symposium. Available from: NJSHS Office, Academy of Applied Science, Raleigh, N.C.

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because we've created part of the problem, we have to learn to work with plants to protect them more effectively and safely than we have in the past. And considering the variety of plant products produced, our partnership should be a fruitful one.

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