Elephant-Sized Amoebas

by Kay Holmes and Cecilia Miller
Grade level: Middle School

Alaska Standards

Science: A10, B1 and B2
Math: M.A.2.1, M.A.2.4, M.A.3.4-6, M.A.5.4, M.D.1.1, and M.E.1.1

Concept: After completing this lesson student should understand that as the size of a cube or three dimensional object increases, its surface area to volume ratio decreases. Student should be able to explain the consequences of increasing a cell's size on its ability to exchange materials with its environment.

Vocabulary: Face, Ratio, Surface Area, and Volume

Materials: Cubes (64 per group), One-Centimeter Graph Paper (1 pieces) and Calculator

Science Background Info:
Amoebas consist of only a single cell. Most amoebas can't even grow large enough to be seen without a microscope. That's because as a cell gets larger, it needs more food and produces more waste. Therefore, more materials must be able to move into and out of the cell through the cell membrane. To keep up with these demands, a growing cell needs a larger surface area through which to exchange materials. As the cell's volume increases, its outer surface grows too. But the volume of a cell (the amount a cell will hold) increases at a faster rate than the area of its outer surface. If a cell gets too large, its surface area will have too few openings to allow enough materials into and out of it.

Gear-Up 1

Ask the following questions: Why can't amoebas grow to be as large as elephants? An amoeba is a single-celled organism. Amoebas, like most cells, are microscopic. If an amoeba could grow to the size of a quarter, it would starve to death. To understand how this can be true, build a model of a cell and see for yourself.

Start by having students draw a two-dimensional hypothetical cell using a sheet of 8_ by 11 sheet piece of paper. Don't give any size guidelines. Select one drawing where the cell is small and select another that is significantly larger. Try to select two that have approx. equal lengths and widths. Explain that in order to simplify calculations we will start by "making" all shapes into a square. Trace these onto acetate and project on an overhead to demonstrate the process of determining perimeter and area for the two selected cells. Have students draw cells for side lengths given in table below.

Explore

Examining Perimeter and Area

Students draw squares with the side lengths given on the graph paper. Using the table below: Calculate the perimeter and area for each rectangle by either counting or using formulas. Find the ratio of the perimeter to area in both fraction and simplified forms.

Side Length	Perimeter (P)	Area (A)	Ratio (P/A)
1 cm			
2 cm			
4 cm			

Generalize:

Discuss observations about changes in the perimeter and the area (see calculations below). Perimeter is also doubled while the area is quadrupled (four times).
What happens to the ratio? (half as big) Do you think that these patterns will continue?

Side Length	Perimeter (P)	Area (A)	Ratio (P/A)
1 cm	4 cm	1 cm^2	4/1 = 4 (4 to 1)
2 cm	8 cm	4 cm^2	8/4 = 2 (2 to 1)
4 cm	16 cm	16 cm^2	16/16 = 1 (1 to 1)
8 cm	32 cm	64 cm^2	32/64 = 0.5 (_ to 1)

Investigation/Experiment 1

Examining Surface Area and Volume

Students create cells using 1-centimeter cubes with the side lengths given. In the table below: Calculates the area of one face (A = s x s or s^2), the surface area (s x s x 6) and the volume (s x s x s or s^3) with formulas given or by counting faces or cubes. Finds the ratio of the surface area to volume in both fraction and simplified forms.

Side Length	Area of 1 face	Surface Area (S.A.)	Volume (V)	Ratio (S.A./V)
1 cm				
2 cm				
4 cm				

Interpret 1

Discuss observations about changes in the area of one face, total surface area and the volume (see calculations below). The area of one face and the surface area increase by a factor of four. Why is it the same for a face as the surface area? What happens to the volume as the side length doubles? (The volume is eight times larger.) What happens to ratio as side length doubles (half as big)? Do you think that these patterns will continue? How would you find out?

Side Length	Area of 1 face	Surface Area (S.A.)	Volume (V)	Ratio (S.A./V)
1 cm	1 x 1 = 1 cm^2	1 x 6 = 6 cm^2	1 x 1 x 1 = 1 cm^3	6/1 = 6 (6 to 1)
2 cm	2 x 2 = 4 cm^2	4 x 6 = 24 cm^2	2 x 2 x 2 = 8 cm^3	24/8 = 3 (3 to 1)
4 cm	4 x 4 = 16 cm^2	16 x 6 = 96 cm^2	4 x 4 x 4 = 64 cm^3	96/64 = 1.5 (1.5 to 1)

Apply

Discuss the following questions: As a cell grows larger, does the ratio of total surface area to volume increase, decrease, or stay the same? (decreases) Which is better able to supply food to the cell – the cell membrane of a small cell or a large cell? (small cell) Generalize about size and ratio of S.A./V in regards to nutrients. (A small cell has a higher surface-area to volume ratio than a large cell allowing more nutrients to enter).

Gear-Up 2

Discuss the following: We have discovered that size makes a difference in the surface area to volume ratio. A large cell amoeba needs more food and therefore must produce more wastes. Ask the following: Does the shape of a cell make a difference to ability to remove wastes? To understand whether shape can make a difference, build different shape models of cells to test.

Explore

Examining Perimeter and Area of difference shapes

Students draw different size rectangles with the area of 16 cm^2 given on the graph paper. Using the table below: Lists the dimensions for each rectangle. Calculates the perimeter for each rectangle by either counting or uses the formula ($2s_1 + 2s_2$ or $2l + 2w$). Finds the ratio of the perimeter to area in both fraction and simplified forms.

Side Dimensions	Perimeter (P)	Area (A)	Ratio (P/A)

Generalize

Discuss observations about the shapes formed. What do you notice about the perimeters? (4 cm different) Which shape has the least perimeter? (square) For what type of situation might this be good? (Buying fencing for a yard) What do you notice about the ratio? (the greater the perimeter, the higher the ratio) What shape has the best ratio? (rectangle)

Side Dimensions	**Perimeter (P)**	**Area (A)**	**Ratio (P/A)**
4 x 4	4 x 4 = 16 cm	16 cm^2	16/16 = 1 (1 to 1)
2 x 8	2(2) + 2(8) = 20 cm	16 cm^2	20/16 = 1.25 (1 _ to 1)
1 x 16	2(1) + 2(16) = 34 cm	16 cm^2	34/16 = 2.125 (2 1/8 to 1)

Investigation/Experiment 2

Examining the effect of shape on Surface Area and Volume

Students create different cell shapes using 1-centimeter cubes with the volume of 8 cm^3. In the table given: Lists the dimensions for each shape. Calculates the surface area $2(s_1 \times s_2) + 2(s_2 \times s_3) + 2(s_1 \times s_3)$ with formula given or by counting faces. Finds the ratio of the surface area to volume in both fraction and simplified forms.

Shape	**Dimensions**	**Surface Area (S.A.)**	**Volume (V)**	**Ratio (S.A./V)**
1			**8**	
2			**8**	
3			**8**	

Interpret 2

Discuss observations about changes in the shapes formed. What do you notice about the surface areas? (very close) Which shape provided the most surface area? (rectangle) Which shape provided the least surface area? (cube) Do you think this is always true? What do you notice about the ratio? (the greater the surface area, the higher the ratio)

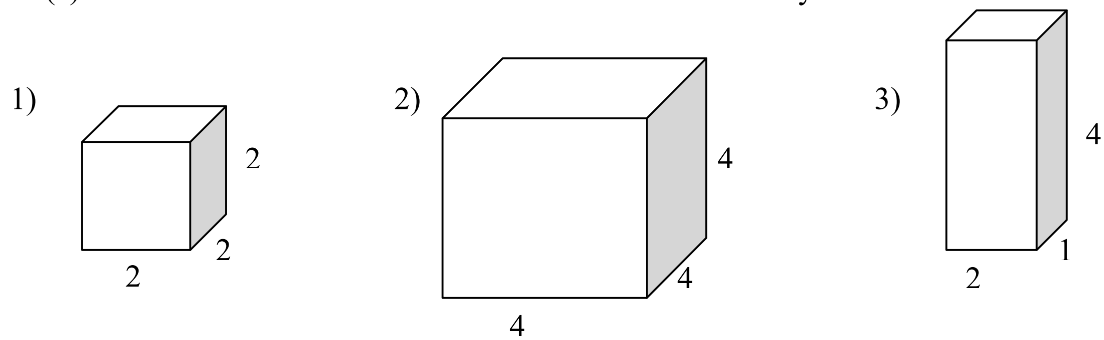
Shape	**Dimensions of the sides**	**Surface Area (S.A.)**	**Volume (V)**	**Ratio (S.A./V)**
1	2 x 2 x 2	2(2 x 2) + 2(2 x 2) + 2(2 x 2) = 24	**8**	24/8 = 3
2	1 x 2 x 4	2(1 x 2) + 2(2 x 4) + 2(1 x 4) = 28	**8**	28/8 = 3.5
3	1 x 1 x 8	2(1 x 1) + 2(1 x 8) + 2(1 x 8) = 34	**8**	34/8 = 4.25

Apply

Discuss the following questions: As a cell shape changes from a cube to a rectangle (with a given volume), does the ratio of total surface area to volume increase, decrease, or stay the same? (increases) Which is better able to supply food to the cell – the cell membrane of a cubic cell or a rectangular cell? (rectangular) Generalize about shape and ratio of S.A./V in regards to cells removing wastes. (A rectangular cell has a higher surface-area to volume ratio than a cubic cell allowing wastes to be removed).

Assessment

Assume that three food molecule per cubic unit of volume per minute is required for the cells below to survive. If one molecule can enter through each square unit of surface per minute, the cells below are (a) too big and would starve, (b) too small and would starve, or (c) at a size that would allow them to survive. Show how you know.



Shape	Surface Area	Volume	Food Molecules	Cells area
1	4 x 6 = 24	$2^3 = 8$	3 x 8 = 24	c
2	(4 x 4) x 6 = 96	$4^3 = 64$	3 x 64 = 192	b
3	2(2x1) + 2(1 x 4) + 2(2 x 4) = 28	2 x 1 x 4 = 8	3 x 8 = 24	a

Assessment Rubric Criteria: (Ratings: 3-Excellent, 2-Good, 1-Poor, 0-Not Done)

- Surface area for each cell correctly calculated.
- Volume for each cell correctly calculated
- Food Molecule requirement for each cell correctly calculated
- Student accurately predicts life or death or each cell
- Work neatly and clearly shown for all of above