Name: Period:

Cell Size Lab (AP version): Write Up and Data Sheet

Introduction: SPECULATE! How are these four facts connected? (answer below)

- Cells are small
- Flatworms live in oceans, ponds, and streams. The ones in oceans can be up to a foot long, but flatworms are always very flat. These animals have no blood, heart, or lungs. Yet they have no trouble getting oxygen to their cells.
- When you get cold, you hold your arms against your body.
- Elephants have big, flat, ears to help themselves stay cool.

A flatworm

_____

_____

_____

Key Definitions
Diffusion: the movement of molecules in a gas or liquid to move from where they're concentrated, to where they're spread out. Think of a drop of ink put into water.
Ratio: A ratio is a *relationship*. If someone is 70 inches tall (5'10") and his/her waste size is 35", then his/her height to waist ratio would be *2:1.* That means 2 units of height to every 1 unit of waist.
Surface area to volume ratio. *Surface area is* the amount of surface on an object, cell, organism, etc. *Volume* is the amount of space something fills.

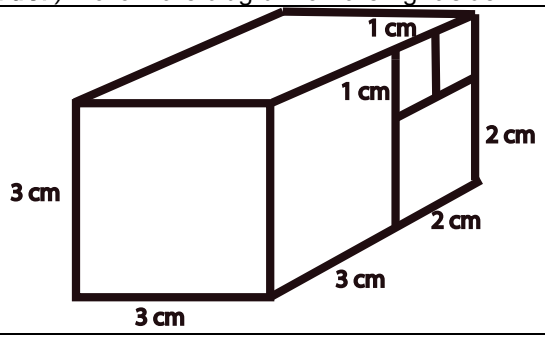
Key Question: how does the relationship between surface area and volume affect the shape and size of cells and organisms.

Lab Supplies

1 razor blade 1 block of phenolphthalein/NaOH agar, in a beaker.
1 flask of vinegar 1 spoon 1 metric ruler.

Procedure (**note:** ***you have to cut the cubes in correct order***). Follow the diagram on the right side.

1. Cut the largest cube: 3 cm by 3 cm by 3 cm.
2. Cut a 2 by 2 by 2 cm cube from what's left.
3. Cut a 1 by 1 by 1 cm cube.
4. Cut a 0.5 by 0.5 by 0.5 cm cube.
5. Put all four cubes in the beaker.
6. At the signal, pour the vinegar into the beaker so that it covers all four cubes. Use the spoon to periodically turn the cubes.
7. Remove all cubes after _____ minutes. Place them on a paper towel and gently blot them.



Calculations for Table 1: The Surface Area: Volume ratio

We start with some math:

A: Length of one side of cube (cm)	**B:** Surface area in cm^2 Cube Surface area = (length) x (width) x 6	**C:** Volume in cm^3 Cube volume = Length x length x length	**D:** Ratio of surface area to volume (surface area/volume) Column B/C
.1 (example)	.1 x .1 x 6 = .06 cm^2	.1 x .1 x .1 = .001 cm^3	60
.5			
1			
2			
3			
5			
10			

BAR GRAPH of SURFACE AREA TO VOLUME RATIO

Surface area to volume ratio (Table, 1, column D)	**12**						
	11						
	10						
	9						
	8						
	7						
	6						
	5						
	4						
	3						
	2						
	1						
	Length of side in cm (Column A)	**0.5**	**1**	**2**	**3**	**5**	**10**

Checking understanding:

1. As the length of a side of a cube decreases, the ratio of the cube's surface area to volume _____ because _____ _____
2. A big cube has _____ surface area than a small cube, but its ratio of surface area to volume is _____.
3. A whale has _____ surface area than a bacterial cell, but the bacterial cell has a higher _____ of surface area to volume.

Diagram 1: Cross sections of cubes after _____ minutes (until the smallest cube becomes totally white)

	Cube 1 (0.5 cm)^3	Cube 2 (1 cm)^3	Cube 3 (2 cm)^3	Cube 4 (3 cm)^3
DRAWING: Try to draw to scale: carefully measure the dimensions of the cube *not* reached by diffusion (the part that's still magenta)				
Length of the side of the magenta cube inside in cm				
Depth of penetration of vinegar in cm				

Table 2: The % of Cube Reached by Diffusion

(a) Length of side (cm)	(b) S.A.: vol. ratio	(c) Total Volume (a^3)	(d) Length of side of "inner cube" (part not reached by diffusion)	(e) Volume of area that's still magenta (d^3)	(f) % of cube reached by diffusion (c-e)/c * 100
0.5	12:1	.125cm^3	0	0	(0.125-0)/0.125* 100 = 100%
1.0					
2.0					
3.0					
5.0					

Interpreting what you've observed:

1. The vinegar entered the cubes by _____.

2. Pretend that these cubes were cells. Keeping in mind that many substances get into and out of cells by diffusion, what advantage do small cells have over big cells?

3. Why do you think that living things that are not microscopic consist of millions or trillions of tiny cells, instead of just one huge cell?

INVESTIGATION: Cut a long, flat piece of agar. Figure out its surface area to volume ratio. Time how long it takes vinegar to diffuse into it. Explain.

_____

_____

_____

Analysis

1. Reviewing the Math

a. As a cube gets bigger, its ratio of surface area to volume _____.

b. As a cube gets smaller, its ratio of surface area to volume _____.

c. As objects get bigger, why does volume increase so much more rapidly than surface area? *Think of the formulas for surface area and volume*

_____

_____

2. Concepts from the Lab (ANSWERS WILL REPEAT!!!)

a. The movement of a substance from where it is more concentrated to where it is less concentrated is called _____.

b. The vinegar entered the agar cubes by _____.

c. For the vinegar to enter into the cubes, it had to go through the cube's _____.

d. Because the 3 cm cube had only _____ units of surface area for every 1 unit of volume, the vinegar was only able to diffuse into a (HIGH or LOW) percentage of the cube's volume.

e. Because the .5 cm cube had _____ units of surface area for every 1 unit of volume, the vinegar was able to reach into (HIGH or LOW) percentage of the cube's volume.

f. In our final demonstration, we cut a flat sheet of agar. A flat sheet has a lot of _____ compared to its _____, Because of this _____ surface area to volume ratio, the vinegar was able to diffuse into a _____ percentage of the cube's volume.

3. Applying concepts

a. Pretend that the large cube was a cell, and the vinegar was food. In this analogy, the surface of the cube would be the _____ of the cell, and the inside of the cube would be the _____. The part of the "cell" that remained pink-ish would be _____ because little or no food would have been able to _____ into it.

b. Cells are small because compared to their _____, small objects have a lot of _____ _____ . This makes it easy for things to _____ in and out.

c. Cells in your intestine are very wavy on top. This shape gives them a high _____ _____ to _____ ratio, making it easy for food to _____ into them.


(Intestinal cell)

d. Gills in fish consist of lots of thin flaps of tissue. These thin flaps provide lots of _____ _____ for absorbing _____ from the water.

e. Heat also diffuses in and out through an animal's surface. Because they're so big, whales have a very _____ _____ _____ to _____ ratio. This makes it _____ for heat to escape from their bodies, which helps them survive in cold water.

f. Elephants are the largest land animals. Like whales, they have a relatively _____ surface area to volume ratio. But, because they live in a hot climate, they need to be able to let heat escape from their bodies. Their huge _____ give them a lot of additional _____. Their ears, in other words, act like a car's _____.

g. Flatworms are able to survive without a system for transporting gases like oxygen and carbon dioxide because _____

4. Conclusion. In your own words, explain what you learned in the lab. In each answer, use concepts related to the *surface area to volume ratio* and *diffusion* (of heat or molecules)

A) Surface area to volume ratio means

B) As things get bigger, their surface area to volume ratio

C) Changing the ratio of surface area to volume affects the ability of molecules or heat to move into or out of something because

D) I this lab, we proved that the higher the ratio of surface area to volume, the easier it is for substances to diffuse into or out of them. We did this by

E) Cells are small because of surface area to volume considerations. Specifically, as a cell gets bigger,

F) We have the instinct to fold our arms against our chest when it's cold because …

G) One cup of ice chips melts faster than a one-cup block of ice because the ice chips because…

H) Jackrabbits have big ears because these big ears are an adaptation for …

I) Almost all of the marine mammals are large (whales, walruses, polar bears) because…

TEACHER'S (somewhat incomplete) GUIDE

SET UP

1) Make up the cubes using food grade agar. I like to make a nice, thick agar, so I use about 50 g/liter of tap water. When you're making the agar, add NaOH. Then phenolphthalein. Add NaOH until the agar is bright pink. Pour into a pan to a depth of 3 cm.
2) Using NaOH in the agar allows you to pour vinegar onto the cubes, turning them from pink to clear. Pouring vinegar is A LOT safer than pouring NaOH (I did it the opposite way for about 20 years).
3) Cut out blocks of agar that are 3 cm X 3 cm X 6 cm (which will enable your students to cut out cubes of agar that are 3 cm, 2 cm, 1 cm and 0.5 cm on a side.
4) Do a trial run with the 0.5 cm cube to see how long it takes for that cube to turn completely white. It's usually about six minutes. That's the time you tell your kids to allow the cubes to soak all the cubes for.
5) To make sure that your cubes start out with that thrilling, brilliant, magenta color, soak them overnight (or for a least a few hours) in a dilute NaOH solution.

CONCEPTS:

The most important idea (table 2).
I'm taking a mathematical approach, but empirical results (with good class averages) should give you about the same. Think about it like this: in six minutes, the little cube became completely white. That means that the vinegar needed to penetrate in 0.25 cm on each side, for a total penetration of 0.5cm (because 0.25cm + 0.25cm = 0.5cm, turning that entire cube white).
For the little cube, the % of penetration by diffusion is obviously 100%. But 0.5cm of diffusion should be the same for all the cubes. So for the 1cm cube, there should be an "inner cube" that's 0.5cm on a side (1.0cm – 0.5cm= 0.5cm). If you follow the calculation below, then 87.5% of the 1cm cube's volume should have been reached by diffusion. The calculations for the other cubes are shown below.

(a) Length of side (cm)	(b) S.A.: vol. ratio	(c) Total Volume (a^3)	(d) Length of side of "inner cube" (part not reached by diffusion)	(e) Volume of area that's still magenta (d^3)	(f) % of cube reached by diffusion (c-e)/c * 100
0.5	12:1	.125cm^3	0	0	(0.125-0)/0.125* 100 = 100%
1.0	6	1	.5	.125	(1 - 0.125)/1 * 100 = 87.5%
2.0	3	9	1.5	3.375	(9 – 3.375)/9 * 100 = 57.8%
3.0	2	27	2.5	15.625	(27 – 15.625)/27 * 100 = 42.1%
5.0 (imaginary)	1.2	125	4.5	91.125	(125 – 91.125)/125 * 100 = 27.1%

That, in a nutshell, is the whole point of the lab. The smaller the cube, the larger its ratio of surface area to volume, and the higher the % of its area that will be reachable by diffusion in the same amount of time.

ANSWERS TO SELECTED QUESTIONS

Answers to pages 1 to 3: no guide available yet.

ANSWERS TO PART 4. Conclusion. In your own words, explain what you learned in the lab. Answer specifically:
a) What's the relationship between the size of an object and its surface area to volume ratio? What causes this relationship, and, in terms of diffusion of molecules or heat, what's the consequence of this relationship?
As an object gets bigger, its ratio of surface area to volume decreases. This happens because as objects grow in size, their volume increases much faster than their area (because volume is a cubic function, while area is a square function). The consequence of this is that big objects have relatively much less surface for molecules or heat to diffuse in and out of them. Whereas in a given amount of time, a small object can have its entire object volume reached by diffusion, a large object will have only a small amount of its volume reached.

b) How did we prove that the higher the ratio of surface area to volume, the easier it is for substances to diffuse into or out of them?
We proved this through our experiment with agar cubes. After a given amount of time, the large cube had only a small percentage of its volume reached by diffusion, while the smaller cubes had much more of their volume reached by diffusion.

c) Explain why cells are small.
Cells are small because small objects have lots of surface area relative to their volume. Therefore, things can easily diffuse into and out of cells.

d) Explain the reason why we have the instinct to fold our arms against our chest when it's cold.
When we fold our arms, we decrease our surface area (but keep our volume the same). This reduces the amount of body heat that diffuses into the environment.

e) Explain why one cup of ice chips melts faster than a one-cup block of ice
When a block of ice is broken up into chips, the surface area of the block is vastly increased. This makes it much easier for heat from the environment to penetrate into the ice chips, making them melt much faster.

f) Explain why jackrabbits have big ears (hint: they live in the desert, and heat can also diffuse)
Their huge ears give them additional surface area that allows them to release their heat into the environment.

g) Explain why animals that live in cold water (whales, walruses, polar bears) are large.
By being large, these animals have a relatively low surface area to volume ratio. This makes it difficult for heat to diffuse from these animals' bodies into the environment. For these animals, that is a good thing, allowing these animals to conserve heat.