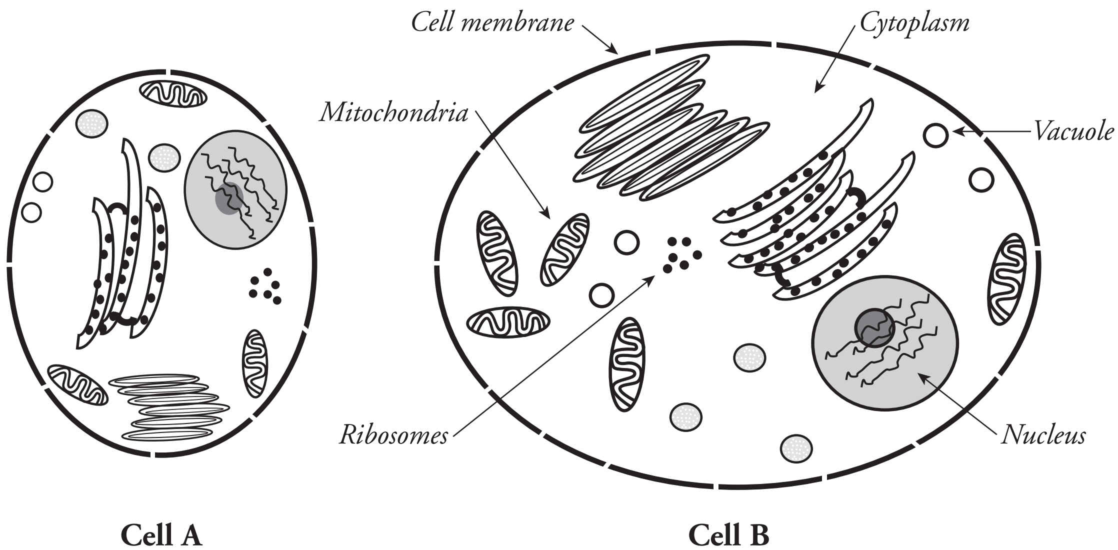
Cell Size

What determines the size of a cell?

Why?

Sometimes bigger is better—tall basketball players, more closet space, and savings accounts may come to mind. What about cells? Does having big cells make an organism bigger or better? Would having larger cells be an advantage to an organism? If so, why do cells divide rather than continue growing? Maybe there is an advantage to being small.

Model 1 – Investigating Cell Size



1. Are the cells shown in Model 1 plant or animal cells? Explain your answer.

   The cells are animal cells. They lack a cell wall.

2. Label Cell B in Model 1 with the following structures.

cell membrane	cytoplasm	nucleus
ribosomes	vacuole	mitochondria

   See Model 1.

3. Compare the smaller cell to the larger cell in Model 1.

   a. Which cell has a larger surface area (more cell membrane surface)?

   Cell B, the larger cell, has a larger surface area than cell A.

   b. Which cell has more channels in its cell membrane that can transport molecules (nutrients, oxygen, and waste products) in and out of the cell?

   Cell B, the larger cell, has more cell membrane channels than cell A.

4. Compare the smaller cell to the larger cell in Model 1.

   a. Which cell has more mitochondria?

   Cell B, the larger cell, has more mitochondria than cell A.

   b. Propose an explanation for why the cell in part *a* would need more mitochondria for proper functioning of the cell.

   Since the cell is larger it will need more ATP to run cell processes.

5. What would be the consequences for a cell if the cell membrane was not large enough to have adequate channels for bringing in nutrients and removing waste?

   Answers will vary. The cell would not be able to maintain homeostasis or carry out its function; it would starve without nutrients, be unable to produce energy without oxygen, be unable to perform protein synthesis without amino acids, be poisoned by waste build-up, etc.

6. Compare the smaller cell to the larger cell in Model 1.

   a. Which cell has a larger volume?

   Cell B, the larger cell, has a larger volume than cell A.

   b. Imagine a glucose molecule entering the cell membrane. Would that molecule be able to reach the mitochondria faster if the cell had a smaller volume or a larger volume? Explain.

   The transport of a molecule from the cell membrane to the mitochondria would be faster in a cell with a smaller volume because there would be less distance to travel.

   c. As the mitochondria metabolize the glucose, they produce carbon dioxide waste. Would the CO_2 molecules be able to leave the cell faster if the cell had a smaller volume or larger volume? Explain.

   The CO_2 would be able to leave a cell with a smaller volume faster because there is less distance to travel.

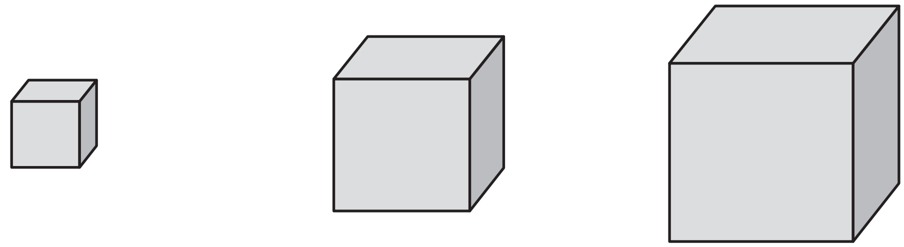
7. Consider your answers to the previous questions. Is bigger always better for a cell? Explain.

   Bigger is not always better. A large surface area is better for transporting molecules across the cell membrane, but a small volume is better in terms of efficiency of transporting molecules throughout the cell.

STOP

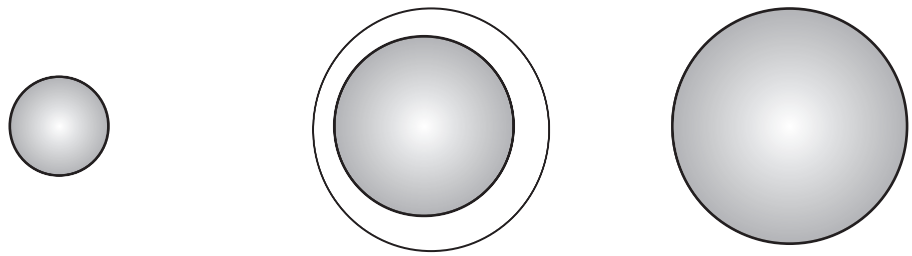
Model 2 – Comparing Shapes

Cubes



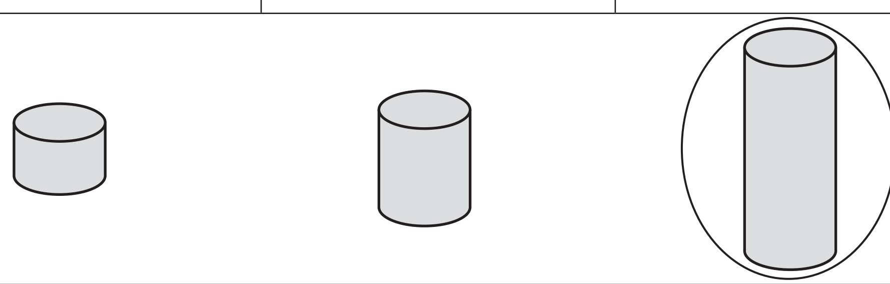
Side	1 cm	2 cm	4 cm
Surface area	6 cm^2	24 cm^2	96 cm^2
Volume	1 cm^3	8 cm^3	64 cm^3
Surface Area-to-Volume Ratio	*6:1*	*3:1*	96:64 = 1.5:1

Spheres



Diameter	1 cm	2 cm	4 cm
Surface area	3 cm^2	13 cm^2	50 cm^2
Volume	0.5 cm^3	4.2 cm^3	34 cm^3
Surface Area-to-Volume Ratio	*6:1*	*3:1*	*1.5:1*

Cylinders



Diameter × Height	1 cm × 1 cm	1 cm × 2 cm	1 cm × 4 cm
Surface area	4.7 cm^2	7.9 cm^2	14 cm^2
Volume	0.8 cm^3	1.6 cm^3	3.1 cm^3
Surface Area-to-Volume Ratio	*6:1*	*5:1*	*4.5:1*

8. Label the sets of shapes in Model 2 with each of the following: cubes, spheres, cylinders.

   See Model 2.

9. Calculate the surface area and volume values that are missing in Model 2. Divide the work among the members of your group and check each other's work.

   See Model 2.

10. Consider the data in Model 2.

    a. Describe the change in the surface area of the cube when the length of the side doubles.

    The surface area is four times larger.

    b. Describe the change in the volume of the cube when the length of the side doubles.

    The volume is eight times larger.

    c. When a shape gets larger, which increases at a faster rate, surface area or volume?

    The volume will increase at a faster rate.

12. Calculate the surface area-to-volume ratio for each shape in Model 2. One example is given in Model 1 for this calculation.

    See Model 2.

13. For all three of the shape sets, describe the change in the surface area-to-volume ratio as the size of the shape increases.

    For all three of the shapes, the surface area-to-volume ratio decreases as the size of the shape increases.

14. Considering your answer to Question 7, is it more desirable for a cell to have a small surface area-to-volume ratio or a large surface area-to-volume ratio? Explain your answer in terms of the functions of a cell.

    It is best for a cell to have a large surface area and small volume. Therefore, a large surface area-to-volume ratio is more desirable.

15. Circle two figures in Model 2 that have a similar surface area (within 1 cm^2 of each other).

    a. Do the two figures have the same volume?

    No, the sphere has a larger volume despite its slightly smaller surface area.

    b. Which shape has a more desirable surface area-to-volume ratio?

    The cylinder has a larger surface area-to-volume ratio.

16. In multicellular organisms some cells need to be large because of the functions they perform (*i.e.* nerve cells, muscle cells). What shape would be most desirable for these larger cells?

    A long, cylindrical shape.

STOP

Extension Questions

17. Propose, by means of a sketch, geometrical shapes of cells that would allow a balance of function and materials movement for each of the following situations. (*Hint:* Think about which aspect of shape would help the cell best carry out its given function.)

    a. Long-distance communication.

    Answers will vary, but may include long, thin cylinders or other shapes with a large surface area and small diameter.

    b. Stretching.

    Same as above.

    c. Storage.

    May include a spherical shape for maximum volume.

    d. Covering and protecting.

    May include a sheet-like shape with a large surface area.

    e. Importing large quantities of material for transfer to other cells.

    May include a spherical shape for maximum surface area-to-volume ratio.

18. Among unicellular eukaryotes, cell sizes differ greatly. *Amoeba* and *Paramecium* organisms are animal-like protists that are heterotrophic, have no cell wall, and are several times larger than most human cells. What might be some reasons why these unicellular organisms have larger cells than cells with similar traits (heterotrophic, lacking cell walls) that are found in multicellular organisms?

    Answers will vary and may include that the cells are not "specialized" and have to carry out all functions necessary for the organism to survive, such as obtain food, reproduce, locomotion, defense, etc.

Teacher Resources – Cell Size

Learning Objectives

1. Describe the change in the surface area-to-volume ratio in a three-dimensional shape as the size of the shape increases.
2. Explain the advantages of a large surface area for a cell.
3. Discuss the disadvantages of a large volume for a cell.

Prerequisites

1. Students should be able to name and describe the function of common organelles for eukaryotic cells.
2. Students should have basic knowledge of general cell processes such as information storage, production of energy, and removal of wastes that are required to achieve homeostasis.
3. Students should be able to calculate surface area and volume of cubes and spheres.
4. Students should be able to calculate a ratio.

Assessment Questions

1. Consider two spherical cells. One is 150 micrometers while the other has a diameter of 300 micrometers. Which has the greater surface area-to-volume ratio?
   a. the smaller diameter cell
   b. the larger diameter cell
   c. they have the same surface area-to-volume ratio
2. Which of the following best describes why cells do not indefinitely continue to increase in size?
   a. Cells do not have enough DNA to allow them to grow very large.
   b. Cells have only enough resources to grow to a certain size and then they have to stop growing.
   c. As cells become larger, their surface area-to-volume ratio decreases and they are no longer able to function properly or efficiently.
   d. The size of the cell is directly related to the size of the organism, so smaller organisms have smaller cells and larger organisms have larger cells.
3. Summarize the reasons why very large cells are fairly rare among multicellular eukaryotes.

Assessment Target Responses

1. *a.*
2. *c.*
3. *Very large cells would experience difficulties with transport of materials in and out of the cell, potentially leading to shortages of raw materials and a build-up of waste products.*

Teacher Tips

- Calculators will be needed for this activity—one per group is adequate and can reinforce process skills and student roles.
- Students will need to calculate the surface area and volume of three different shapes. If they do not remember the formulas for these calculations you may need to provide them.

	Cube	Sphere	Cylinder
Surface Area	$6(l \times w)$	$4\pi r^2$	$2\pi r^2 + 2\pi rh$
Volume	$l \times w \times h$	$(4/3)\pi r^3$	$\pi r^2 h$

- If students have additional knowledge of cell processes (respiration, DNA replication, active transport, production and export of proteins), their conclusions and connections can be much more in-depth.
- *Extension Question 17* is challenging and would make a good class discussion or application question after completion of the activity.
- The Learn.Genetics website (accessed January 2012) has a very nice scale model "From Coffee Bean to Carbon" with various eukaryotic cells, organelles, and prokaryotes. http://learn.genetics.utah.edu/content/begin/cells/scale/

Notes