Tested Studies for Laboratory Teaching
Proceedings of the Association for Biology Laboratory Education
Vol. 33, 314-321, 2012

Making Cell Structure and Function Interactive and Interesting

Sarah Salm[1], Jessica Goldstein[2], and Lauren Goodwyn[1]

[1]Borough of Manhattan Community College, Dept. of Science, 199 Chambers St, New York NY 10003 USA
[2]Barnard College, Biology Department, 3009 Broadway, New York NY 10027 USA
(**ssalm@bmcc.cuny.edu; goodwyn@bmcc.cuny.edu;jgoldste@barnard.edu**)

Teaching cell structure and function in an interactive and meaningful way is a challenge. Students frequently spend the laboratory session labeling cell pictures in the manual or attempting to view cell slides. They are taught to draw what they see on the slide but are unsure how to do that and resort to either copying a diagram from the lab manual, drawing from a photograph in the manual, or just filling their diagram with random spots and blobs that they think represent the cells that are on the slides. They may not fully understand the relationship between surface area and volume, or how cells are adapted for function. In this modified version of the common cell lab, agar blocks and colored dye are used to teach the relationship between surface area and volume. In addition, students create different types of cells on the bench using easy-to-make foam models, and students are taught to measure the relative sizes of the cells and their organelles in order to understand spatial considerations in a cell.

Keywords: cells, surface area and volume, foam models

Student Outline

Introduction

Diffusion is the key process by which useful substances like oxygen and nutrients move into cells and waste products leave. This lab will help you understand the relationship between cell size and diffusion efficiency. Remember, diffusion is movement of molecules from a region where they are highly concentrated to an area where there are fewer molecules. Keep this question in mind: what affects the efficiency of diffusion through cells? The lab will also help you understand how cell structure is related to function. You will make models of cells according to descriptions of their function. You will also learn how to determine the size of cells and their organelles.

Part A. Examining Volume to Surface Area Relationships

Materials for the Table

For this lab, each table will need

- Three cubes of 3% agar-phenolphthalein (1 cm, 2 cm, and 3 cm on a side)
- 0.4% NaOH solution
- A clear plastic ruler
- Razor blade or scalpel
- A plastic spoon
- A paper towel
- A 100 mL beaker

Procedure

1. Line a portion of your bench with paper towel or a bench protector sheet.
2. Using the plastic ruler and razor blade, cut the agar into three blocks of the following dimensions: 1 cm x 1 cm x 1 cm; 2 cm x 2 cm x 2 cm; 3 cm x 3 cm x 3 cm
3. Calculate the surface area and volume of each agar cube and record these values in the Table 1 below.
4. Place the three agar cubes in the beaker
5. Carefully fill the beaker with 0.4% NaOH so that the cubes are completely submerged.
6. After 15 minutes, remove the cubes with the plastic spoon and place them on the paper towel.
7. Blot the cubes dry. Use the razor blade to carefully cut each cube in half. The phenolphthalein in the agar cubes reacts with the NaOH and changes the color of the cube to pink. The cubes are exposed to NaOH, and then cut in half. You can tell how far the NaOH diffused into the cube by the change in color that it causes. By measuring the distance of the color change you can determine the relationship between diffusion and the surface area and volume of the cubes.
8. As soon as you have cut the cube, measure the length and width of the uncolored portion.
9. Fill in Table 1 using your measurements.

Questions

1. If you need to have a molecule move into the center of the cell in 10 minutes, which cube is the best model? Why?
2. Which cube represents the cell with the least effective diffusion? Why?
3. Why are bodies made of trillions of small cells and not fewer, larger ones?
4. What problems would a cell with a small surface to volume ratio have?
5. If the agar blocks represent cells, which is the most likely to survive and why?
6. In all experiments, there are sources of error. Discuss sources of error in this lab.

Table 1. Diffusion of NaOH into the agar cubes.

Cube size	*Surface area l*w*number of sides]*	*Volume [l*w*h]*	*Surface area/volume ratio*	*Volume of uncolored portion*	*Volume diffused [total volume-uncolored volume]*	*Percent diffusion [(volume diffused/total volume)*100]*
1 cm/side						
2 cm/side						
3 cm/side						

Part B: Build a cell

In this exercise, you will build a variety of cells using the available foam parts. You will learn how to estimate cell and organelle sizes from these models.

Materials for the table

- String
- Meter stick and small clear ruler
- Foam organelles
- Scissors

Procedure

1. Create a basic cell shape on the surface of your lab bench.

a. As cells are microscopic, you will be building a representation of cell at the macroscopic level. To do so accurately, you have to **scale** the cell up in size. For the cell you will make, the nucleus measures 5 µm in diameter. However, we need to have a much model to work with. For the purposes of this lab, 1 µm will be represented by 2 cm.

b. Get a nucleus and measure its **diameter** (D) to the nearest centimeter. _____cm.

c. This nucleus belongs in a cell with a diameter 6 times the size of the nucleus. What is the diameter (D) of the cell you will need to make? _____cm.

d. To make the cell membrane you have to figure out the **circumference** of the cell. The formula for circumference is π x D. What is the circumference of your cell going to be? _____cm ($\pi = 3.14$)

e. Get string and cut it to the above length. This string will represent the cell membrane of your cell.

f.. Place the string on your table so that it makes a circle. Measure the diameter of your circle to ensure you have the size you calculated above.

2. The diameter of your cell is 60 cm. Assume the cell you made represents a real cell that has a diameter of 30 micrometers (µm). How many micrometers does one centimeter represent in your cell? _____

3. What is the diameter of the nucleus in your cell in µm?_____

4. Cells are like miniature factories. They have many machines each with a different, critical function. These machines are the organelles of the cell. You will now build a basic cell. List all the organelles (and their functions) needed to make a basic cell in Table 2

5. Once you have created a list, ask your instructor to approve your list.

6. Once the list is approved, get one of each of the organelles and place them in your circle.

7. For each organelle, calculate its dimensions in µm and record in Table 2.

8. **Discuss** how many organelles of each type you should have in a typical cell.

9. **Draw your cell** in the space at the end of the lab.

Table 2. Organelles and their functions in a cell.

Organelle	Foam color	Function	Diameter (μm)

10. Create a cell specialized for diffusion.

a. You have made a basic cell, but most cells are more specialized. You now need to consider modifying this cell to make it more efficient for diffusion. (Remember what you learned in Part A.) What changes would you need to make to create a cell that allows substances to move from outside the cell on one side, through the cytoplasm and out the other side of the cell? List those changes here.

_____

_____

b. One cell that is excellent for allowing diffusion to occur through it is a **squamous** cell. Squamous cells are not round, they are quite flat. Pull your cell into as flat a shape as possible. What organelle is most preventing the cell from being as flat as possible? _____.

c. Swap that organelle for a flatter one of the same kind and then flatten your cell further.

d. Measure the length of your squamous cell to the nearest cm. _____ Calculate the diameter in μm. _____.

e. Measure the cell at its narrowest point. _____ cm. Compare this to the diameter of your original cell. Given the diameter and the height of this cell, why do you think the squamous cell is better at allowing a substance to pass through?

_____

_____

11. **Draw your cell** in the space at the end of the lab.

12. Create a cell specialized for energy production.

    a. Recreate your original cell.

    b. Now make a cell that would be very good at producing ATP.

    c. Which organelle(s) did you add? _____

13. Create a cell specialized for protein production (Plasma cell making antibodies for example).

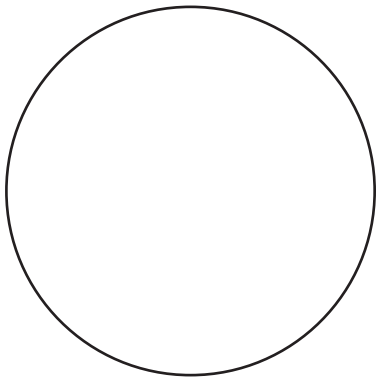
    a. Recreate your original cell.

    b. Now make a cell that would be very good at making protein.

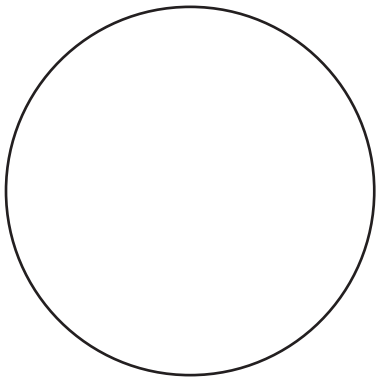
    c. Which organelle(s) did you add? _____

14. Create a cell specialized for detoxification (liver cell or **hepatocyte**).
    a. Recreate your original cell.
    b. Now make a cell that would be very good at making protein.
    c. Which organelle(s) did you add? _____
15. Create a **columnar** cell.
    a. Recreate your original cell.
    b. One cell type you will soon study is a columnar cell. From its name, what shape do you think this cell will have? _____
    c. Create a columnar cell. Measure its height and width.
    d. **Draw your cell** in the space at the end of the lab.
    e. What function do you think a columnar cell might be good for? _____ _____
    f.. Cells are generally surrounded by cells on all sides but one (in other words, they touch other cells on three sides). This cell has only its top exposed. What is the exposed length (or surface length)?_____
    g. Many times cells need to increase their surface length. How could your cell get more surface length without changing the bottom or the sides?

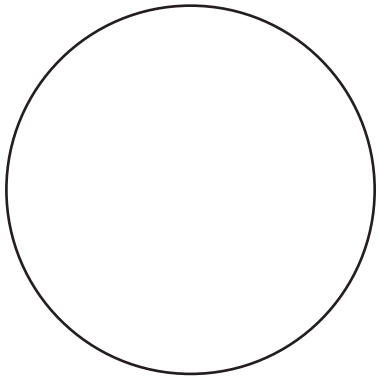
       _____
    h. Cells often get around this problem by creating microvilli, or folds of their plasma membrane, on their upper surface. To make a cell with **microvilli** that has the same dimensions as your current cell, your cell will need to make more plasma membrane. Get more string to increase the surface length and create microvilli. Make sure you are not increasing the other dimensions of your cell. Get your instructor to approve your new columnar cell.
    i.. **Draw your cell** in the space provided.



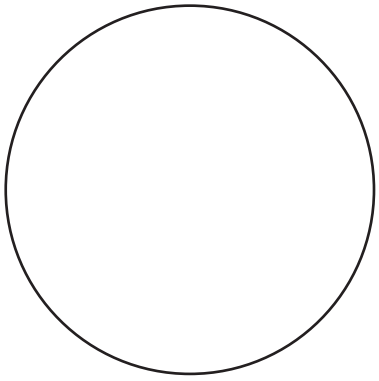
General Cell



Squamous Cell



Columnar Cell



Columnar Cell with Microvilli

Notes for the Instructor

Lab Requirements

1. 0.4% NaOH solution (200 ml per pair).
2. 1% phenolphthalein solution (10 mL per L of 3% agar)
3. 3% agar (1 L per group of 12)
4. Rules, blades to cut agar, gloves
5. String and foam cell parts

Comments

1. Phenolphthalein is potentially hazardous. It causes irritation of skin and eyes and respiratory tract upon exposure. We require that students use gloves for the diffusion experiment. There are alternative methods available such as maltose agar that is put into iodine solutions.
2. We made our agar blocks in blue tip box lids – each lid gives a master block that can be cut in half, with one half for a pair of students. The smaller blocks are cut from this. Scalpels are not ideal for cutting the agar. Actually, something like dental floss works. Alternatively, we also used the very thin, flexible rulers for cutting. It is possible to buy ready-made molds as well.
3. Once the blocks are removed from the NaOH, they must be dabbed quite dry – if there is excess NaOH on the blocks, it turns the inside of the block pink as the cut is made. Also, students must take their measurements as quickly as possible, because the reaction continues after the blocks are removed from the NaOH solution.
4. One thing not covered in this lab is calculating the rate at which diffusion occurs. It is worth doing this because students are often under the impression that the rate of diffusion is faster in small cells than in big cells. If they calculate the rate, they will discover that the rate of diffusion is the same in all block sizes, but that in a small block the NaOH reaches the center of the blocks, while in a big block the NaOH diffuses only a small distance towards the center.
5. We have included a template of the organelles we used for this lab (see Appendix).
6. Suggestions that came from presenting the workshop during the 2012 ABLE meeting, New Mexico State Las Cruces:
    a. Get students to compare different types of cells as well as the different sizes. For example, they can make a "cell" that measures 3 cm x 1 cm x 1 cm and will find that although the cell looks larger than the 1 cm^3 cell, diffusion into it will be as efficient.
    b. To demonstrate plant cells, one can use something like sandwich bag ties to make a cell wall.

About the Authors

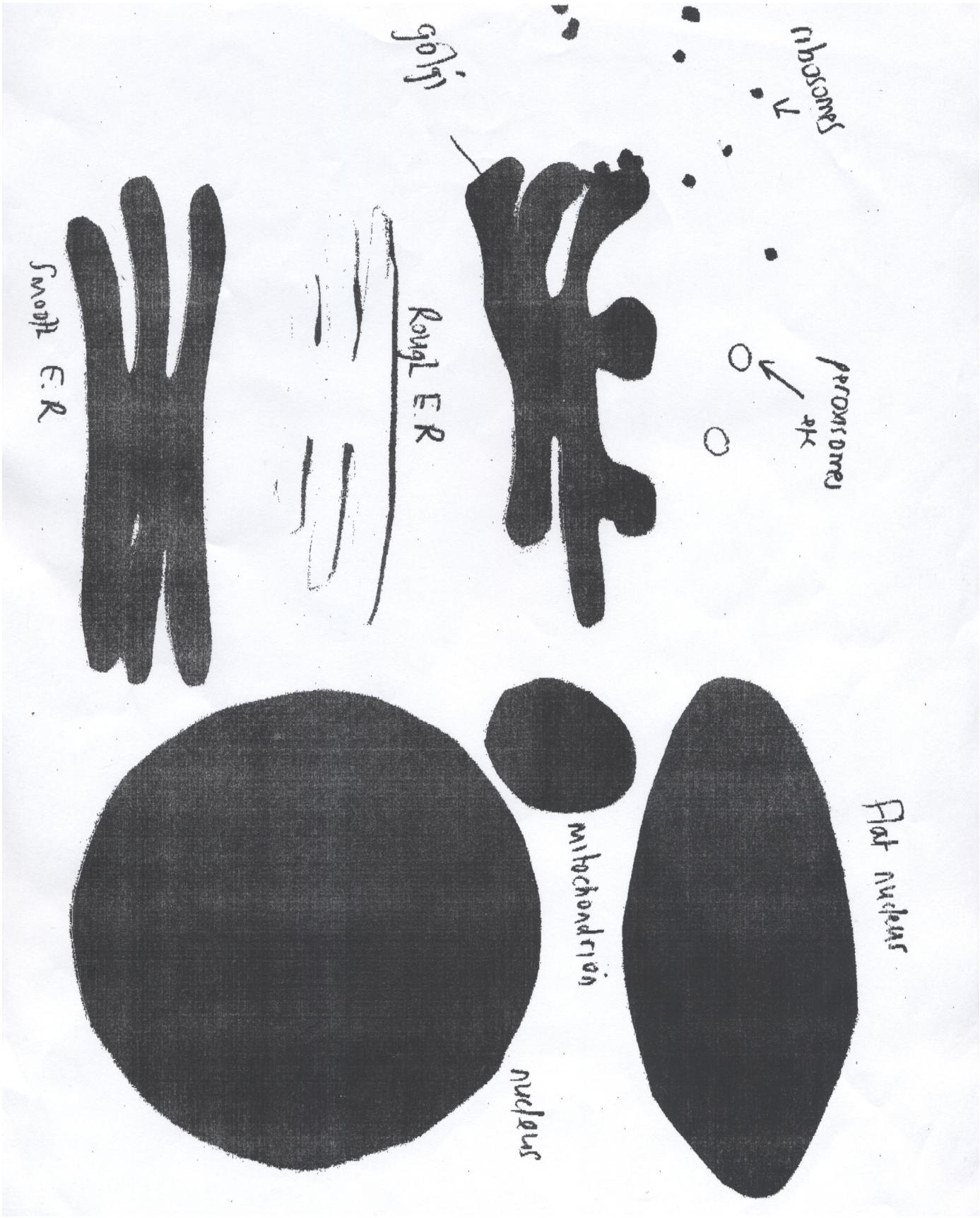
Sarah Salm received her PhD at the University of the Witwatersrand in Johannesburg, South Africa. She did her postdoctoral work at NYU Langone Medical Center, focusing on prostate stem cells, her continued field of research. She cur¬rently teaches Microbiology, Anatomy and Physiology, and General Biology at the Borough of Manhattan Community College.

Jessica Goldstein received a BA in Biology from Macalester College and a PhD in Molecular Cell Biology from Washington University in St. Louis, MO. She is currently a Senior Lecturer in the Biology Department at Barnard College in New York City where she is responsible for coordinating Introductory Biology Laboratory courses for majors and non-majors.

Lauren Goodwyn received her BA (Plan II Liberal Arts), MA (Biology) and PhD (Curriculum and Instruction) degrees from the University of Texas, Austin. She is currently an Associate Professor at the Borough of Manhattan Community College, where she teaches Anatomy and Physiology. She is also the A&P group leader, and the Deputy Chair of the Science Department of BMCC.

Appendix

Templates for drawing organelles



Mission, Review Process & Disclaimer

The Association for Biology Laboratory Education (ABLE) was founded in 1979 to promote information exchange among university and college educators actively concerned with biology learning and teaching in a laboratory setting. The focus of ABLE is to improve the undergraduate biology laboratory experience by promoting the development and dissemination of interesting, innovative, and reliable laboratory exercises. For more information about ABLE, please visit **http://www.ableweb.org/**

Papers published in *Tested Studies for Laboratory Teaching: Proceedings of the Conference of the Association for Biology Laboratory Education* are evaluated and selected by a committee prior to presentation at the conference, peer-reviewed by participants at the conference, and edited by members of the ABLE Editorial Board.

Citing This Article

Salm, S., Goldstein, J., and Goodwyn, L. 2012. Making Cell Structure and Function Interactive and Interesting. *Tested Studies for Laboratory Teaching,* Volume 33 (K. McMahon, Editor). Proceedings of the 33rd Conference of the Association for Biol-ogy Laboratory Education (ABLE), 390 pages. http://www.ableweb.org/volumes/vol-33/?art=35