Student Guide

Linear Diffusion and Cell Signaling

Introduction:
Your ability to read these words is dependent on cell communication. A stimulus (light) reaches the cells in your eyes and those cells propagate (spread) that signal to the cells next to them until the signal reaches your brain. Your brain then translates that signal into letters and words. This process is quite complex, but an important part of this process is dependent on diffusion. Diffusion occurs when one cell releases chemicals into the interstitial fluid (the stuff surrounding the cells) and those chemicals diffuse (spread) to neighboring cells. This process is repeated until the signal reaches your brain. The faster your brain receives the signal, the faster you are able to react to a given stimulus. Drag car racers need to react very quickly to the stimulus of a green light. The driver who processes the stimulus faster gets a "head start" over the other racer.

Diffusion is a naturally occurring process wherein atoms, molecules, nanoparticles, or other small bodies suspended in a background medium move from an area of high concentration to low concentration. The process of diffusion is usually considered to be slow from a macroscopic point of view. While the diffusion process is slow over the length scale of meters, at the nanometer scale diffusion becomes a dominant mode of chemical transport. Atoms, ions, and molecules may diffuse across a span of a few nanometers in a matter of milliseconds or faster. This is relevant to nanotechnology as diffusion is an important process in cell signaling which occurs at the micro- and nanoscales.

In this lab you will explore the concept of diffusion on a macro scale to gain a better understanding of how the cells in your body communicate on the micro and nano scale. Furthermore, you will identify several factors that influence the rate of diffusion and use those factors to postulate ways our body could increase the rate of cell signaling.

Prelab Questions:
1. What will happen to the rate of diffusion if we double the distance it has to travel?
2. What are three things that might make diffusion occur faster?

Vocabulary and Definitions: These should be reviewed before the activity begins. Your teacher may assign as homework or have these as part of a class discussion

1. *Diffusion*
2. *Concentration*
3. *Dilution*
4. *Rate*
5. *Active transport:*
6. *Passive transport*
7. *Nanoscale*
8. *Nanometer*

Materials: (for each lab group of 3-4)

- A clear plastic thin stem pipet
- Metric ruler capable of measuring mm
- Food coloring (red, blue or green)
- Timer/stopwatch
- Aluminum foil
- Petri dish (to hold food coloring)
- Thermometer
- Beakers to hold cold and hot water
- Graph paper or spreadsheet program

Procedure:

You will determine the rate of diffusion for food dye in a thin stem pipet filled with water. The pipet is a macro-model of cell diffusion which occurs at the micro/nano-scale. You will vary the concentration and temperature and compare results with the control.

1. Fill a plastic pipet with water so that the bulb and stem **are completely filled** with water.
2. Hold the pipet so the stem is pointing down and carefully squeeze out **one** drop of water. When you release the bulb there should now be a small amount of air in the tip of the pipet.
3. Place two drops of food coloring on a small piece of aluminum foil or some other non-absorbent material such as a petri dish.
4. With the pipet tip facing down, carefully squeeze the pipet bulb so that the air is evacuated from the tip of the pipet.
5. Have a stop watch or timer ready.
6. Place the tip of the pipet into the food coloring and very slowly "draw-up" the food dye into the tip (**NOTE**: if done too quickly, the food dye will shoot up and mix with the water in the pipet tip; if this happens, begin again).
7. Lay the pipet down on its side next to the ruler so that the top of the food dye is at zero on the ruler. Record how far the dye travels in 20 second intervals. Record each distance traveled in cm and report to the nearest tenth place (ex: 1.5 cm). You may use the data table below or your lab notebook – teacher will tell you which one to use.
8. Record the distance for 10 minutes (30 total data points!)
9. Repeat the experiment in hot or cold water and record the temperature in degrees Celsius.
10. Repeat the experiment after diluting the food dye to half its original concentration.
11. Graph your data for each experiment.

Data Table:

Time (Min:sec)	Diffusion Distance		
	Food Dye	Diluted Food Dye	Hot/Cold Water ____°C
0:00	0.0 (cm)	0.0 (cm)	0.0 (cm)
0:20			
0:40			
1:00			
1:20			
1:40			
2:00			
2:20			
2:40			
3:00			
3:20			
3:40			
4:00			
4:20			
4:40			
5:00			
5:20			
5:40			
6:00			
6:20			
6:40			
7:00			
7:20			
7:40			
8:00			
8:20			
8:40			
9:00			
9:20			
9:40			
10:00			

Analyze the Results:

Plot all three sets of data on the same graph with time on the "x" axis and distance on the "y" axis. Be sure to use appropriate labels and units. Answer the questions below based on your results in your lab notebook:

1. Is your data linear or not? What does this tell you about the rate of diffusion?

2. Which trial had the fastest rate? Which trial had the slowest rate? Does this make sense? Why or why not?

3. When cells communicate with their neighboring cells, they release chemicals which diffuse through the interstitial fluid that separates them. What would allow these cells to communicate more quickly (think about distance, temperature, and concentration).

4. If the distance between two cells is 35 nanometers, how long would it take for the chemicals released from one cell to diffuse to the next cell? (Assume a constant rate of diffusion and use the rate determined from your trial with the control.

5. Why is diffusion and cell signaling considered a nanoscale phenomenon?

Going Further: Your instructor may require you to answer these challenge questions:

1. How would this experiment be more difficult if we were using actual cells instead of plastic pipets to represent the cells?

2. How long do you think it takes for chemicals to diffuse between two cells? (*a cool link to help think about how to answer this question: http://umdberg.pbworks.com/w/page/61013258/Relay%20cells)*

Cleanup: Follow your teacher's instruction. Used food coloring can be safely dumped down the drain. Discard aluminum foil or wash petri dish is used. Pipets may be discarded.

Optional Activity Extension:
Design an experiment to test other variables that you would like to examine their movement. What other variables would you test? Would you want to use the same pipet to observe diffusion or would you change the shape of the container? What type of molecules would you examine? Large versus small? Vitamins, minerals, salts? What about the medium through which your materials will diffuse? Design your experiment and have the instructor approve your design before testing. Write up your results and then share as a short presentation to the class.