



AP Biology Best Osmosis Lab: **KEY**

Water Potential in Potato Cells and French fry Perfection

Introduction: Maintaining water balance is one important function that cells must accomplish in order to maintain *homeostasis*. When placed in different solutions, cells change their water content. *Osmosis* is the diffusion of water through a selectively permeable membrane. Plant cells respond differently to surrounding solutions due to their cell wall. In this investigation, you will:

- observe osmosis in French fries
- graph the percent change in mass the fries after being placed in six solutions
- calculate water potential of cells in solution
- determine the best solution for preparing French fries

Most people, world-wide, love French fries! There is a tremendous difference in really great fries and average fries. Recent foodie recommendations are to vacuum seal potato fries in a starch infusion. As biologists, we have always taught that starch doesn't diffuse, but glucose and sucrose readily diffuse. Let's assume the foodies are on to something with the vacuum and remember that pressure is part of water potential. We know water diffuses by osmosis, even if mixed in a starch solution. In summary, great fries are "doctored up" and have a high surface area for the quick and crunchy product. Another great variable to change for student inquiry would be surface area.

Learning Objective 2.12. The student is able to use representations and models to analyze situations or solve problems qualitatively and quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes.

Note that the word "active" does not necessarily and exclusively mean active transport. In my manual of Enduring Understanding and Essential Knowledge, passive transport is discussed. Essential knowledge 2.B.2.3 states, "External environments can be hypotonic, hypertonic, or isotonic to internal environments of cells."

Materials: Potatoes, French-Fry Maker, Potato Peeler, Portion Cups or small plastic cups, Balance, Water, Sucrose Solutions, Food coloring, Paper Towels, Sharpie, Plastic Wrap, Sharpie, Knife or Scalpel, Calculator, Timer, Colored pencils.

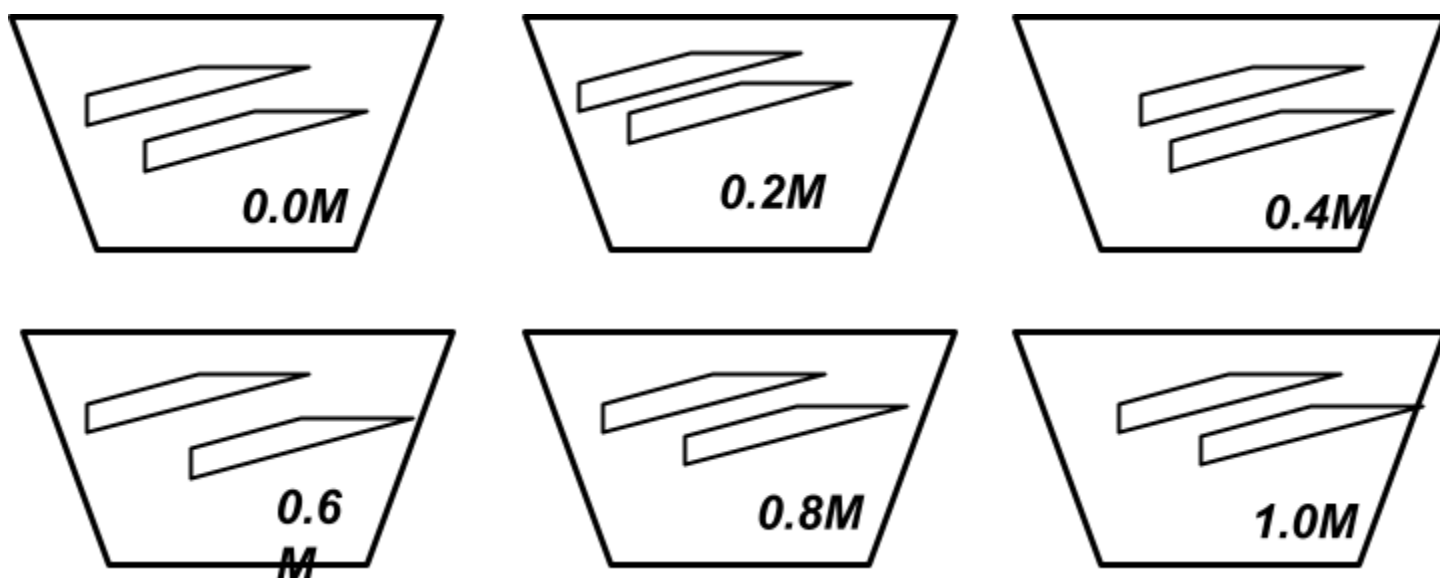
Procedure:

1. Peel potatoes and make 12 “fries” by cutting your potato with the vegetable cutter.
I started out with a fry cutter with a lever and a suction cup that adhered to the lab tables. Over time the lever bent and I found an inexpensive product on amazon (\$2.99). It’s called “Unmengii Fry Fruit Vegetable Chopper French Blade Cutter Potato Slicer Chopper.” It works out better for each lab group to have their own potato, peeler, balance, and fry cutter.
2. Cut each fry to 3cm long.
The ends can be tapered or blunt. Use plastic knives or scalpels.
3. Blot potatoes with a paper towel and record the mass of 6 groups of 2 fries (initial mass). Record mass in **Data Table 1**. *Do not include mass of the cup.*
Surprisingly, most students do not know the meaning of “blot.”
4. Label cups as follows: tap water/0.0 M sucrose, 0.2M sucrose, 0.4M sucrose, 0.6M sucrose, 0.8M sucrose, and 1.0 M sucrose.
Solutions should be in 5 distinct colors with water being clear.
Tap water will be fine.
5. *After recording mass*, place 2 fries in each cup. Fill cups with corresponding **colored** solutions so that the potatoes are covered with solution.
6. Cover cups with plastic wrap and leave overnight at room temperature.
7. The next day, remove fries; gently blot dry, weigh, and record mass in **Data Table 1**.
You may need to demonstrate this. Record keeping and organization is key. Weigh the two fries from each cup together and immediately record data. At this point the qualitative observations can be discussed. For example, the fries in the tap water and the .2M solutions (maybe .4 also) will be full, taut, and hard. The others will be limp and will have shrunk.
8. Determine the percent change in mass for your potatoes [(Final Mass-Initial Mass)/initial mass] x100. Record in **Table 1**.
If data look funny, the students did not use this formula correctly. It’s not uncommon to have a lab group re-do their math.

9. *Optional:* Record classmates' data and compute averages on **Data Table 2**.
10. Graph your average *or* class averages; label axes with appropriate variables.
11. With your lab group, agree on a title for your graph that reflects both variables.

Using a 4-pack of food coloring, try to make 5 distinct colors for the sucrose solutions. Color-coding the solutions prevents students mixing up solutions.

Experimental Model: Color each cup to reflect the corresponding solution color



Data Table 1: Mass of Fries and % Change

Solution Concentration	Initial Mass (of 2 fries)	Final Mass	Loss or Gain?	% Change
0.0 M Sucrose (tap water)				
0.2 M Sucrose				
0.4 M Sucrose				
0.6 M Sucrose				
0.8 M Sucrose				
1.0 M Sucrose				

Data Table 2: (Optional) Class Average

Percent Change in Mass of Potato Fries

Group	1	2	3	4	5	6	7	8	Average
0.0 M Sucrose (tap water)									
0.2 M Sucrose									
0.4 M Sucrose									
0.6 M Sucrose									
0.8 M Sucrose									
1.0 M Sucrose									

Here is some sample data:

Contents in Cup	1	2	3	4	5	6	7	8	Class average
0.0 M sucrose (distilled water)	17%	16.6%	20%	+20.6%	24.912 %	22.9%	16.89 %	18.92 %	19.72%
0.2 M sucrose	7%	17.6%	10%	+6.56	16.03%	6.25%	3.21%	3.69%	8.79%
0.4 M sucrose	3%	7.8%	4%	-2.21%	7.456%	-5.5%	-8.73 %	-1.57 %	0.53%
0.6 M sucrose	-10%	-4.71%	-30%	-17.09 %	-8.854%	-17.07 %	-27.6 %	-20.29 %	-16.95 %
0.8 M	-19%	-9.22%	-26%	-19.93 %	-12.125 %	-23.6%	-36.59 %	-23.05 %	-21.19 %
1.0 M sucrose	-26%	-3.46%	-32%	-25.02 %	-19.235 %	-27.5%	-38.77 %	-21.87 %	-27.18 %

Sucrose Solutions:

0.2M=68.46 g/L

0.4M=136.92g/L

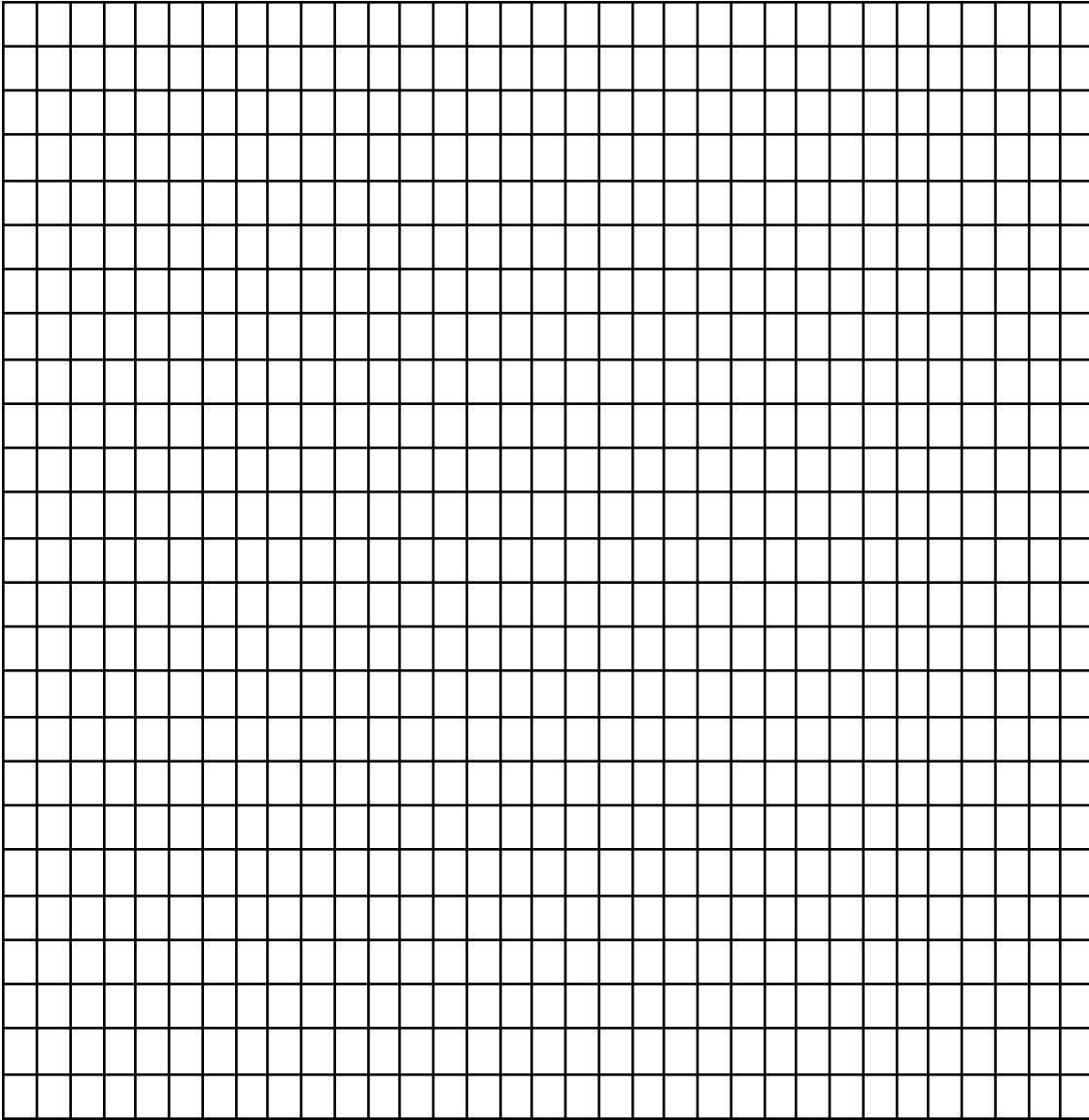
0.6M=205.38g/L

0.8M=273.84g/L

1.0M=342.3g/L

Title: _____

Graph



Relate Osmosis to Water Potential

$$\Psi = \Psi_s + \Psi_p$$

$$\Psi_s = -iCRT$$

i =# ions, C =# moles, $R=0.0831$, T =Kelvin

$\Psi_p = 0$ in open container

Data Table 3: Water Potential Calculations

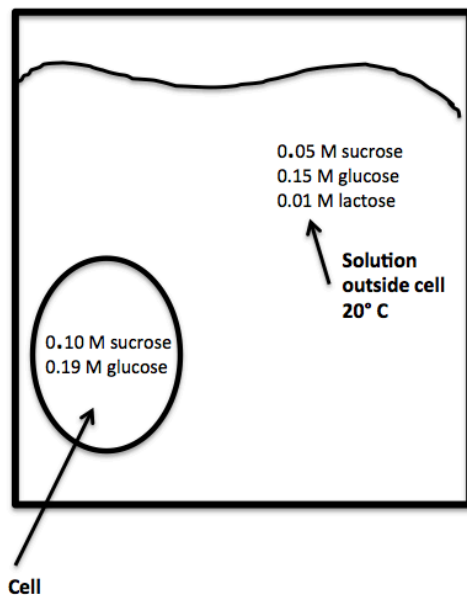
Solution	Show Calculations	Fries: loss or gain	Was solution hypotonic, isotonic, or hypertonic
0.0M Sucrose Water	$-(1)(0)(.0831)$ $(293)=0$	gain	hypotonic
0.2 M Sucrose	$-(1)(.2)(.0831)$ $(293)=-4.86$ $\cong -5$	gain	hypotonic
0.4 M Sucrose	$-(1)(.4)(.0831)$ $(293)=-9.73$ $\cong -10$	gain	hypotonic
0.6M M Sucrose	$-(1)(.6)(.0831)$ $(293)=-14.61$ $\cong -15$	loss	hypertonic
0.8 M Sucrose	$-(1)(.8)(.0831)$ $(293)=-19.47$ $\cong -20$	loss	hypertonic
1.0 M Sucrose	$-(1)(1)(.0831)$ $(293)=24.34$ $\cong -24$	loss	hypertonic

Analysis Questions

1. Which potatoes gained/lost mass?
2. Explain why they gained/lost.
3. What solution is isotonic for potatoes? How did you determine this?
4. Go back to the figure above where you colored the solutions. Next to each solution type, label the solutions as hypertonic, isotonic, or hypotonic.
5. Write a hypothesis that this investigation is testing.
6. What is the independent variable for this investigation?
7. What is the dependent variable for this investigation?
8. What is the control for this investigation?
9. You plan to place the fries in a deep fryer, cook for a few minutes, and serve. Which solution do you soak the fries in before frying?
10. Estimate the water potential of the potato cells. What led you to your estimation?

Water Potential Problem

Note: The selectively permeable membrane on this artificial cell is permeable to monosaccharides, but not disaccharides.



$$\Psi = \Psi_s + \Psi_p$$
$$\Psi_s = -iCRT$$

$i = \# \text{ ions}$, $C = \# \text{ moles}$, $R = 0.0831$, $T = \text{Kelvin}$

$\Psi_p = 0$ in open container

1. Which solute(s) will diffuse into the cell?
2. Which solute(s) will diffuse out of the cell?
3. Which solution is hypertonic...cell or environment?
4. Which way will water move by osmosis?
5. Will the cell shrink, swell, or stay the same?
6. After diffusion of sugar, what is the water potential of the solution outside the cell?

Analysis Answers

1. The tap water, 0.2M, and 0.4M gained, the others lost. Note that with some potatoes, the 0.4M will lose mass.
2. The potatoes that gained mass were placed in a hypotonic solution (high water). Water will move from high water to low water. The potato cells were originally hypertonic.
3. Isotonic is close to the 0.4M solution. This can be determined by looking at the line of the graph. Where the line crosses zero is the isotonic (no loss/no gain).
4. See chart
5. Potato cells will gain mass when put in a hypotonic solution and loose mass when put in a hypertonic solution.
6. Independent variable = the concentration of sucrose
7. Dependent variable = the change in mass
8. Control could vary depending on the hypothesis. Most students will say tap water is the control because it has no sucrose added to it. Some students, thinking outside the box, will say that the isotonic potato cells are the control. I would accept both answers.
9. I would use the tap water, or the 0.2M sucrose because those solutions left larger, more full fries. The extra water adds to crispiness when deep-frying.
10. Between -10 and -15; this is the point between gain and loss.

Water Potential Answers

1. None, both lactose and sucrose are disaccharides
2. Glucose ($0.19 > 0.15$)
3. Cell
4. Into cell
5. Swell
6. $-(1)(.23)(0.831)(293) = -5.6$

Note: # moles = 0.05 Sucrose + 0.17 Glucose (.02 M diffused in) + 0.01 M lactose; total = .23