# Water Kit© Osmosis Lesson

## Objectives

Students will:

- **Define** osmosis as the diffusion of water through a membrane.
- **Construct** and **explain** a physical representation of osmosis in hypertonic, hypotonic and isotonic environments.
- **Compare** the movement of water molecules through a membrane in hypertonic, hypotonic and isotonic environments.
- **Recognize** and **account for** the necessity of aquaporins in water transport across a membrane.
- **Conceptualize** the scaling factor for the water molecule models.
- Quantify the relative size of a water molecule in relation to a typical human cheek cell.

## Materials

- 1 Water Kit© cup per small group
- 1 copy of this packet per person

## Osmosis

Living things must perform vital activities in order to maintain their existence including exchanging gases like $CO_2$ and $O_2$; taking in water, minerals and food, and eliminating wastes. These tasks occur at the cellular level and require that molecules move through a membrane that surrounds the cell. The cell membrane is a complex structure that is responsible for separating the contents of the cell from its surrounding environment and for controlling the movement of materials into and out of the cell.

It is important to understand how water flows in and out of a cell through the membrane as it will directly impact a cell's ability to survive. The passive transport of water across a selectively permeable membrane is called ***osmosis***. **The net flow of water is in the direction toward the highest concentration of solute.**

. . .where molecules become real™

## Water Kit© Osmosis

### Directions

You will explore osmosis by making models of the hypertonic, hypotonic and isotonic states of osmosis and predicting the flow of water in each state.

You will use the water molecule and ion models in the Water Kit© and the graphic image of a cell on page 10 to make your models. After exploring each state, you will document your findings by drawing your model on the smaller cheek cell image of a cell and answering the questions in the blue boxes.

1. Note that the water molecules and ions are at a different scale than the image of a cell on page 10. Answer the questions below to explain the differences in scale.

### Questions

1. Based on the size of the water molecule models, how large would the image of the cell be, if they were at the same scale?

   ______________________________________________

   ______________________________________________

   ______________________________________________

2. Explain your process in determining what the size the cell image would be, if it was at the same scale as the water molecular models.

   ______________________________________________

   ______________________________________________

3. What source(s) did you use to determine the relative proportion of a water molecule and a cheek cell?

   ______________________________________________

   ______________________________________________

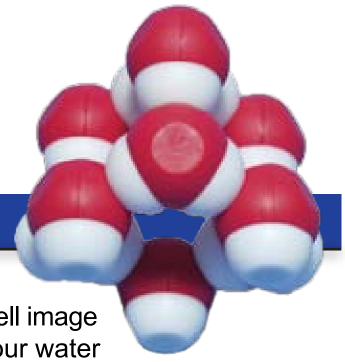
4. Are all cells the same size? ______________________________

5. What does this imply about your calculations?

   ______________________________________________

   ______________________________________________

   ______________________________________________

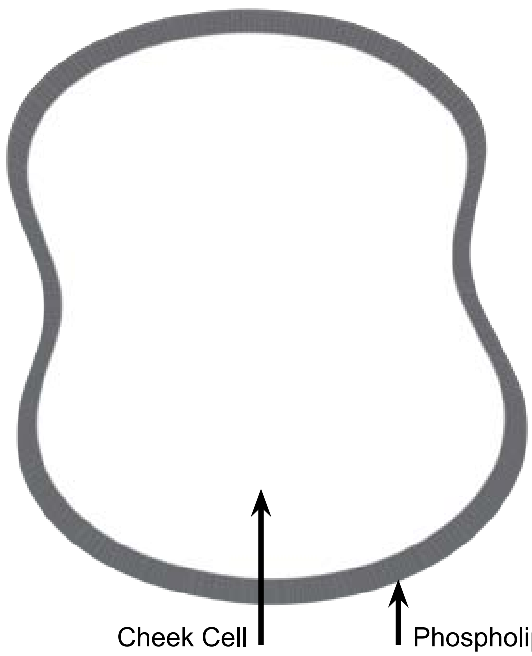


## Water Kit© Osmosis

2. Place your sodium ($Na^+$) and chloride ($Cl^-$) ion models on the outside of the cell image (page 10). Place four water molecules ($H_2O$) on the inside of the cell and four water molecules on the outside of the cell.

   In the image below, draw how you placed the molecules and ions on the large image. Use $H_2O$ to indicate water, Na to indicate sodium and Cl to indicate chloride. Draw a circle around the solute.

### Hypertonic




### Questions

1. Identify the solute. Where is the solute located?______________________________

2. Water may pass through the membrane but the solute may not. ***Predict the direction of the net flow of the water by drawing arrows to indicate this on your diagram***. Explain why the water would flow in this direction.

   ________________________________________________________________

   ________________________________________________________________

3. When water flows in the direction you predicted, what happens to the volume of the cell?

   ________________________________________________________________

   ________________________________________________________________

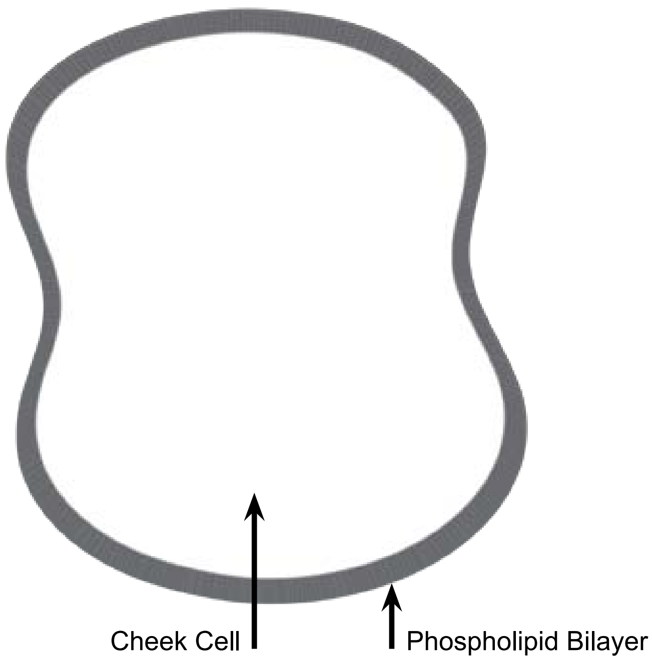
**When the concentration of solutes outside the cell is higher than the concentration of solutes inside the cell, the net flow of water will be out of the cell. This type of a solution is referred to as *hypertonic*.**

## Water Kit© Osmosis

3. Again, using the molecules and image on page 10, set up a physical representation where the concentration of solutes is higher inside the cell than outside. This type of solution is referred to as ***hypotonic***.

   Sketch your placement of the water and solute molecules in the diagram below. Indicate the net flow of water in this system.

### Hypotonic




### Questions

1. Where is the initial concentration of solute molecules higher?

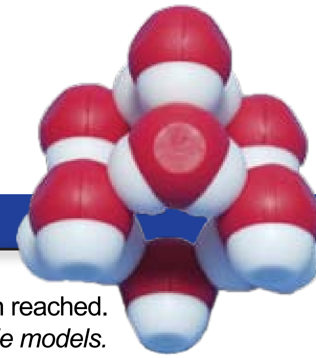
   ______________________________

2. ***Predict the direction of the net flow of the water by drawing arrows to indicate this on your diagram.*** Explain why the water would flow in this direction.

   ______________________________
   ______________________________
   ______________________________

3. What happens to the volume of the cell in this system?

   ______________________________
   ______________________________
   ______________________________
   ______________________________



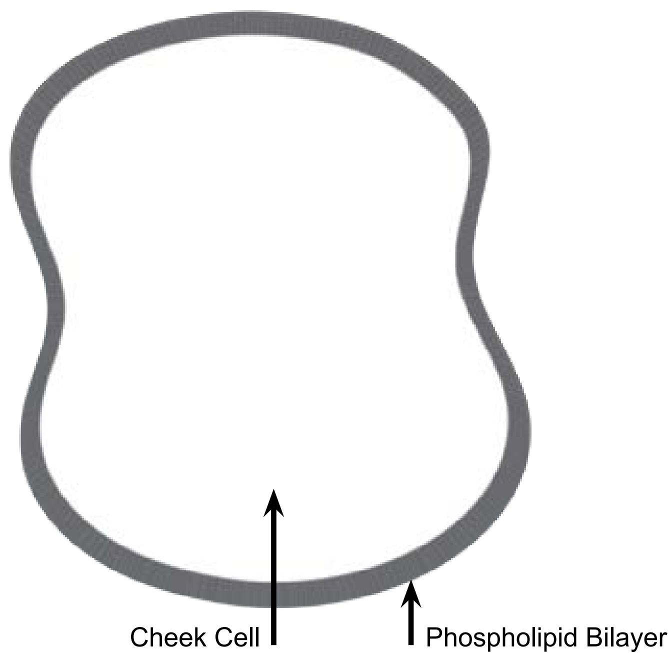
## Water Kit© Osmosis

4. Next, with the models, create a model of a system where ***equilibrium*** has been reached. *You will have to work with another group in order to use two sodium and chloride models.*

   Place one $Na^+$ both inside and outside the cell. Place one $Cl^-$ both inside and outside of the cell. Place an equal amount of water molecules inside and outside of the cell. Sketch the placement of the water and solute molecules in the diagram below. Indicate the direction of the net flow of water.

   When the concentration of solutes is equal on either side of the cell membrane, a state of equilibrium has been reached. Water still continues to flow through the membrane but at an equal rate in and out of the cell. This type of solution is said to be ***isotonic***.

### Equilibrium




## Questions

1. Explain what happens to the flow of water in an isotonic solution.

   ______________________________________________

   ______________________________________________

   ______________________________________________

Questions Continued on Next page

## Water Kit© Osmosis

### Questions

2. Using the vocabulary of osmosis, explain what may happen to the vegetation along the side of a road when excessive amounts of salt are used during the winter.

_______________________________________________

_______________________________________________

_______________________________________________

3. Thinking *osmotically*, explain why grocery stores spray water on their fresh vegetables.

_______________________________________________

_______________________________________________

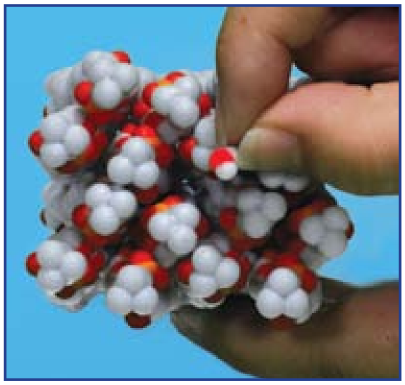
_______________________________________________

4. Explain what will happen to a blood cell if it is placed in a 1.5% salt solution when normal blood has a salt concentration of 0.9%. Sketch a model of this system in the space below.

_______________________________________________

_______________________________________________

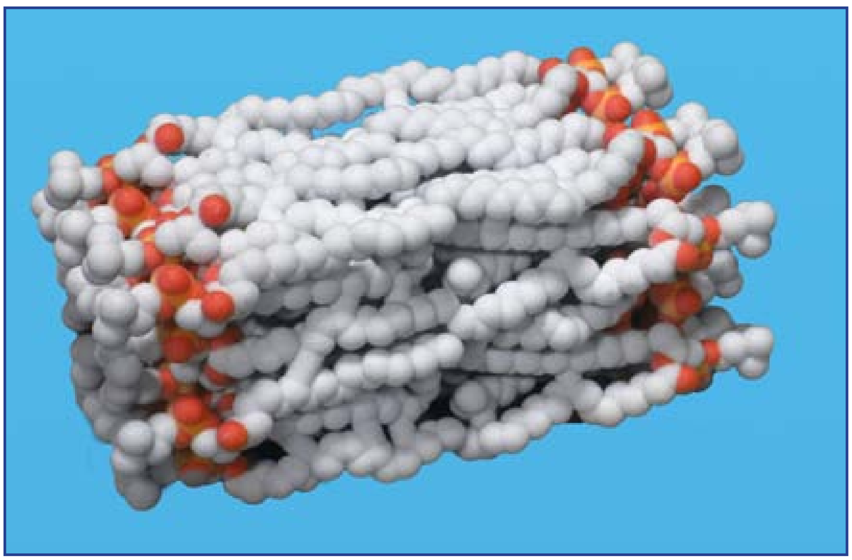
## Aquaporin



### Phospholipid Bilayer

Water molecules are small enough to diffuse across the phospholipid bilayer (left photo), but the middle zone of the cell membrane (bottom photo) is highly hydrophobic, since it consists of compact carbon atoms. Given the nature of water, the hydrophobia of the middle zone impedes the passage of water across the phosphilipid bilayer.

*Passage of the water molecules.*

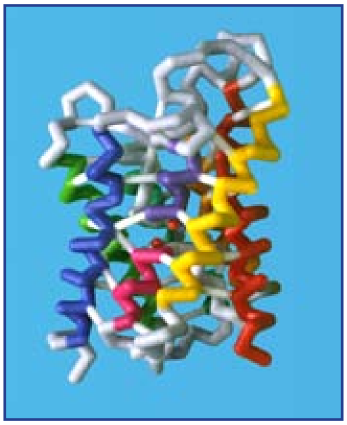


*This space filled model of a phospholipid bilayer is printed on a 3-D ZCorp Printer by 3D Molecular Designs.*

### Discovery of Aquaporin

The movement of the water molecules through cell membranes is too rapid to be explained by ***unaided diffusion*** alone. Transport proteins called ***aquaporins*** facilitate the diffusion of water across the cell membrane. While studying Rh factors in red blood cells, Peter Agre made the serendipitous discovery of a protein that later became known as aquaporin 1.  The 1992 discovery was considered so important that Agre was awarded the 2003 Noble Prize in Chemistry.  To date, 13 variants of aquaporins have been discovered in humans.

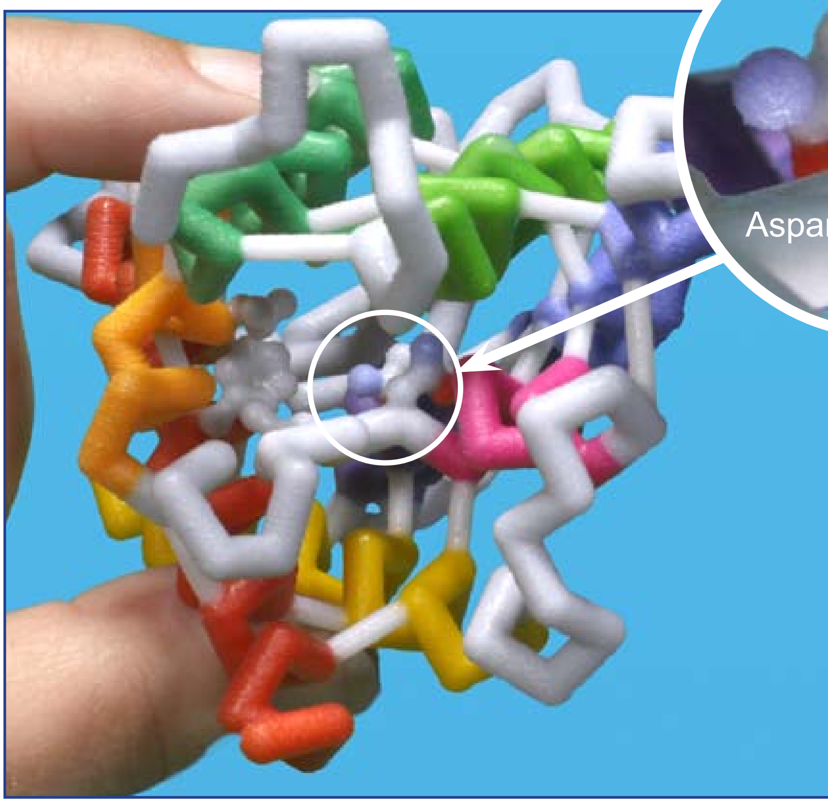
# Aquaporin



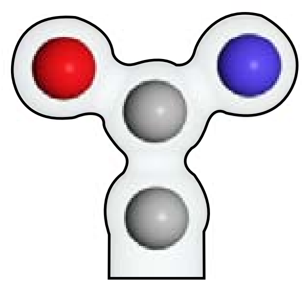
## Aquaporin Structure

Aquaporin consists of six alpha helices and two half-alpha helices.

Two asparagine (ASN) amino acids – ASN 78 and ASN 194 – are found at the turns of the two half alpha helices (colored magenta and purple in the photo). These are located at the narrowest part of the hour-glass shaped channel and form the **filter** that allows water to pass through aquaporin.




*This alpha carbon backbone model of aquaporin is printed on a 3-D ZCorp Printer by 3D Molecular Designs. It is based on 1J4N.pdb and features the six alpha helices and two half-alpha helices of the structure and the two asparagine involved in selectively moving water through the channel. From this perspective you can see portions of the six alpha helices (red, orange, dark green, light green, blue and yellow), two half-alpha helices (magenta and purple) and one of the two asparagines.*



**Asparagine Side Chain**

**Color Key**

- oxygen
- nitrogen
- carbon

3-D Molecular Designs
. . .where molecules become real™

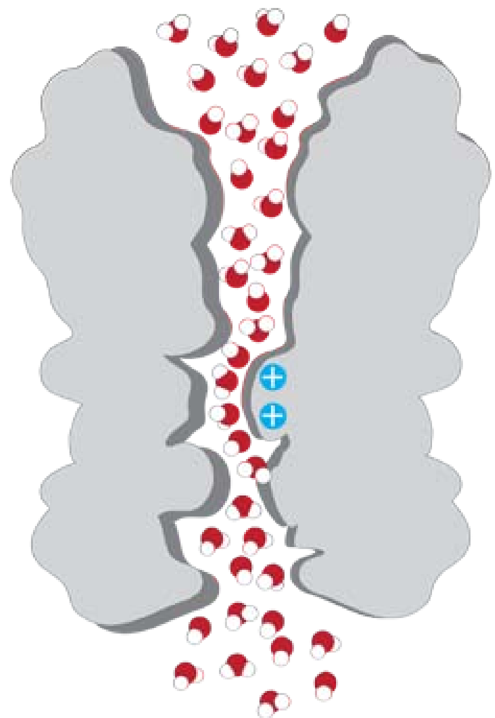
# Aquaporin

## Function

Water molecules rapidly flow in single file through the aquaporin channel. The ability of aquaporin to selectively bind water molecules and prevent other molecules from entering the channel is referred to as the aromatic /arginine selectivity filter.

While the process is not fully understood, many researchers[1] believe that water molecules roll over as they reach the narrowest part of the channel, where the arginine are located.

In computer simulations the oxygen (red) atom of each water molecule points down as it moves through the channel toward the two asparagine.  To pass through the narrow opening each water molecule binds first to one asparagine and then to the second. In this process each water molecule rolls over so that the oxygen points up toward the asparagine — now from the opposite side of the passageway — and passes through the remaining portion of the channel.  (See illustration right.)



*Water Channel*

**Note:** Water molecules form hydrogen bonds with asparagine. The partially negative oxygen atom forms a hydrogen bond with the partially positive nitrogen (blue) atom of the asparagine amino acid.

Most of the amino acids in the aquaporin channel are hydrophobic, which enables water molecules to move freely within the channel until binding with asparagine.

For an animation and explanation from the National Institutes of Health (NIH) Center for Macromolecular Modeling & Bioinformatics and the University of Illinois at Urbana-Champaign, go to *http://www.ks.uiuc.edu/Gallery/Movies/aquaporin-movie-explanation.html*

## Questions

1. What factors may influence the passage of water through a membrane?

________________________________________

________________________________________

2. Water is reabsorbed in the cells of the kidneys. What would happen to the rate of diffusion of water if the number of aquaporin protiens decreased? Explain your answer

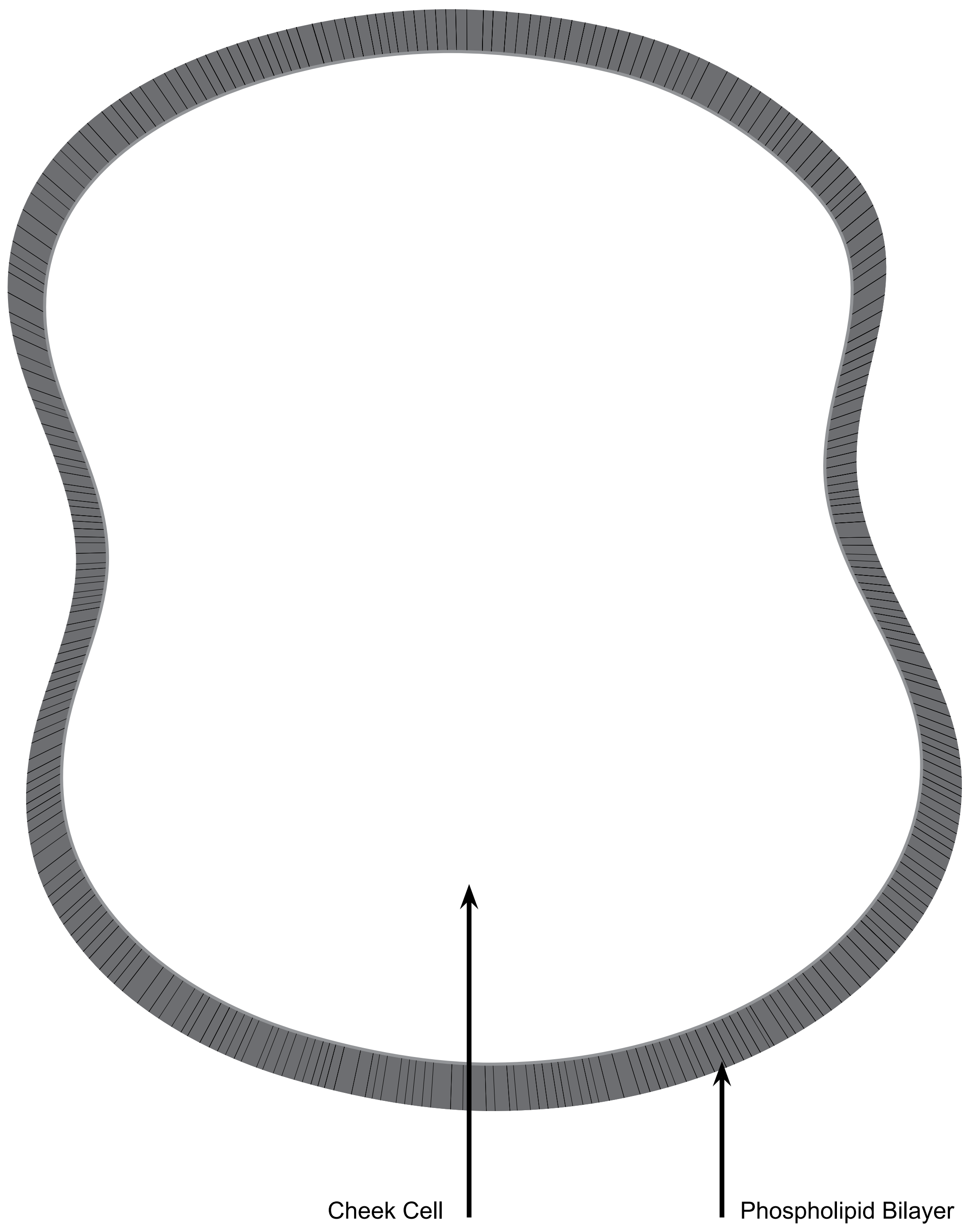
________________________________________

________________________________________

________________________________________

________________________________________

[1] *Tajkhorshid E, Nollert P, Jensen MØ, Miercke LJ, O'Connell J, Stroud RM, Schulten K (2002). "Control of the selectivity of the aquaporin water channel family by global orientational tuning". Science* ***296*** *(5567): 525–30. doi:10.1126/science.1067778. PMID 11964478.*


Cheek Cell
Phospholipid Bilayer