Teacher's Guide

When a Cell Talks, everyone listens!

Grade Level: High School

Subject area: Biology

Time required: (2) 50 minute classes

Learning Objectives: through hands on activities: 1. Understand diffusion; understand cell signaling.

Summary: This is a two part lesson focused on diffusion and cell communication. In Part 1, students will use the classic starch iodine diffusion activity. This activity can be done in any life science class. It can be used as an introduction to diffusion or as a refresher activity for advanced students.

The Part 2 activities introduces students to cellular communication. In these activities, students will determine if one cell has an effect on the cellular condition of other cells within close proximity. For both lessons, it will be important that students understand that these cell processes are occurring at the nanoscale.

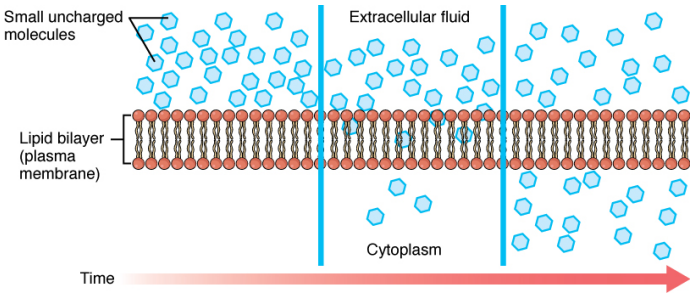
Lesson Background: With the evolution of science and the new innovations in technology, we are now able to see life at the smallest of scales…..the nanometer scale. Nano refers to the 10^{-9} power, or one billionth. In these terms it refers to a meter, or a nanometer, which is on the scale of atomic diameters. For comparison, a human hair is about 80,000 - 100,000 nanometers thick!

Most plant and animal cells are between 1 and 100 micrometers and therefore are visible only under the microscope. Can your students convert cell size to nanometers? Nanoscience is the study of atoms, molecules, and objects whose size is on the nanometer scale (1 - 100 nm). Biologically speaking, while most cells are micrometers in size, cellular activity occurs at the level of nanometers!

The cell membrane serves as a boundary between the cell and its external environment. Embedded in the cell membrane are specialized receptors called integrins that provide vital communication links between the interior and exterior of the cell. These receptors function a number of ways to ensure the homeostasis within the cell. Changes can lead to the activation of integrins which in turn influences the relationship of the cell with its environment.

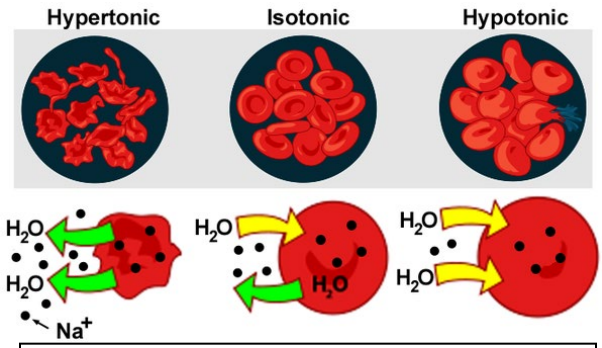
Part 1. Diffusion:
In our bodies, the task of maintaining homeostasis is carried out by cell transport, moving molecules into and out of a cell. This phenomenon occurs across the outer covering of a cell, the plasma membrane. The membrane is *selectively permeable* meaning that it only allows select nano-sized molecules to move across it. Transport through the plasma membrane occurs

in two basic ways: passive and active transport. *Active transport* is carried out with the help of ATP, an intracellular source of energy. *Passive transport* is carried out when the concentration or pressure differences influence movement. A concentration gradient exists when there is a difference in concentration between the inside and outside of the cell. The numbers of molecules present influence the cells concentration on either side. The greater the numbers of molecules, the higher the concentration on that side.



Simple diffusion across cell membrane. Wikipedia: https://commons.wikimedia.org/w/index.php?curid=30131172

Diffusion, a passive process, is the movement of molecules from an area of higher concentration to an area of lower concentration. *Osmosis*, a special form of diffusion, is the movement of solvent; usually water, down its concentration gradient. When cells move molecules from one side to the other, it can possibly cause the cell to change shape and or/weight. A solution surrounding the cell that contains the same solute/water concentration as the inside of the cell is considered *isotonic*. There is no water movement because equilibrium already exists. A solution surrounding the cell that contains a higher concentration of solutes than are present inside the cells is considered *hypertonic*. The cell will loose weight or crenate and shrink in an effort to establish equilibrium. A solution surrounding the cell that contains a lower concentration of solutes than are present in cells is considered *hypotonic*. The cell will gain weight and possibly lyse or burst in an effort to establish equilibrium.



Hypertonic, isotonic & hypotonic solutions & impact on red blood cells. Wikipedia: https://commons.wikimedia.org/wiki/File:Osmotic_pressure_on_blood_cells_diagram.svg

Both diffusion and osmosis occur naturally in many places within the human body. The kidneys, which filter blood, carry out both of these processes on a regular basis. Sometimes, matter limits our body such as in kidney failure. When matter limits the body, it can no longer conduct those functions necessary to maintain life. Imbalance of variable factors such as blood pressure, pulse, respiration rates, and glucose levels, can eventually lead to organ failure if not addressed. If organs fail, the body is no longer be able to maintain life.

Pre-requisite Knowledge: Knowledge of the cell's permeable membrane; diffusion; concentration gradient.

Part 1. Diffusion and Cell Signaling: a nanoscale phenomena

Before beginning the activity, you may want to review the vocabulary. It is recommended that the students either read in their text about diffusion at the cellular level or that they watch one of the recommended videos.

Materials: (per group of students)

- One clear/translucent soap storage box (approximately 7 in x 5 in)
- Four pieces of dialysis tubing* (soaked overnight)
- 1% starch solution
- Lugol's solution
- String
- Distilled water

* If dialysis tubes are unavailable, plastic bags from the dollar store work well. You should find a "cheap" type of bag that will allow for movement of the Lugol's solution.

Dialysis tubing sources:

Carolina Biological Supply: https://www.carolina.com/dialysis-tubing/dialysis-tubing/FAM_684202.pr

Flinn Scientific: https://www.flinnsci.com/products/biology/cells/dialysis-tubing/

Wards Scientific: https://www.wardsci.com/store/catalog/product.jsp?product_id=17274046

Lugol's soltuon and starch solution are also available from science suppliers for educators.

Safety Information: Goggles should be worn in any lab where liquids and chemicals are used. Aprons and gloves are recommended as the Lugol's solution can stain clothing.

Vocabulary and Definitions:

1. *Selectively permeable:* a property of cell membranes that only allows certain molecules to enter or exit the cell i.e., only allows select nano-sized molecules to move across it.
2. *Diffusion*: a passive process, is the movement of molecules from an area of higher concentration to an area of lower concentration.
3. *Osmosis*: a special form of diffusion, is the movement of solvent; usually water, down its concentration gradient.
4. *Homeostasis*: in biological systems, it is the tendency to maintain stability while adjusting to conditions that are optimal for survival.
5. *Active transport:* is the movement of molecules or ions against a concentration gradient (from an area of lower to higher concentration). This does not ordinarily occur so such transport requires energy often carried out with the help of ATP, (an intracellular source of energy) and enzymes.
6. *Passive transport:* is carried out when the concentration or pressure differences influence movement. A concentration gradient exists when there is a difference in concentration between the inside and outside of the cell.
7. *Hypertonic*: a solution where the concentration of solutes is greater outside the cell than inside it.
8. *Hypotonic*: a solution where the concentration of solutes is greater inside the cell than outside of it.

9. *Isotonic*: where the concentration of solutes outside the cell is equal to the concentration of solutes inside the cell.
10. *Integrins*: various glycoproteins that occur on cell surfaces that are involved in the adhesion of cells. These are transmembrane receptors that facilitate extracelluar adhesion.
11. *Nanoscale*: measured in nanometers; typically referring to materials between 1 and 100 nm but others use up to several hundred nanometers.
12. *Nanometer*: $1x10^{-9}$ or one billionth of a meter.
13. *Nanotechnology*: Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.

Advance Preparation: Dialysis tubes should be soaked overnight. Put the starch and Lugol solutions in smaller bottles for each group of students.

Suggested Teaching Strategies: Before doing the Part 1 activity, have students complete the vocabulary section either as homework or as a class discussion. The definitions should be discussed in class to ensure there are no misconceptions. As an introduction, it is recommend to use one of the PowerPoints or Kahn Academy online videos prior to the beginning of the lesson.

Directions for the Activity – Part 1:
This can either be done as a model activity by teacher or students can be divided into small groups for completion.

1. Provide students with 4 pieces of soaked dialysis tubing (or plastic bags). Instruct students to tie or clamp, one end of each of the dialysis tubing.
2. Fill two of the tubes with 1% starch solution and seal the open ends of tubing or bags.
3. Fill the remaining tubes with the Lugol's solution and seal the open ends.
4. Instruct students to pour just enough water into the soap box to cover the bottom. Then, place the four tubes into the soap box starting first with the Lugol filled tube, then the starch tube, then the other Lugol tube and finally ending with the starch tube.
5. Cover the soap box with the lid to keep the tubes moist (This mimics the cellular environment. Remind students that cells are in a warm, moist environment.).
6. Instruct students to record observations every 5 minutes on the student sheet or lab notebook. Record any color changes.

Analysis of Results:
1. Were there color changes in any of the tubes?
2. Which tubes changed color first? Did you notice a pattern?
3. Hypothesize why there was a color change.
4. Explain why it was important to keep the system moist.
5. How does the proximity of the dialysis tubing mimic the proximity of cells?

6. The dialysis tubing bags serve as a model for a community of living cells. In what ways is the model an accurate portrayal of cell systems and in what ways is it flawed?
7. Describe two specific examples of cell-to-cell communication, naming the type of cell and what chemical message is passed.

Lab Questions Answer Key

Question 1: The starch tube will initially appear milky white; the iodine tube will initially be copper colored. The starch tube will turn dark as the iodine diffuses into it. The iodine tube will become lighter in color as the iodine leaves.

Question 2: Answers will vary.

Question 3: The color changes indicates diffusion is occurring with the iodine reacting with the starch to cause a color change. It shows that the iodine can enter the tube containing the starch but that the starch is not entering the tube containing the iodine. The iodine molecules must be small enough to diffuse into the starch tube but the starch moleclues are too large to enter the iodine tube.

Question 3: The system must be kept moist for the solutions to diffuse across the dialysis tubing (membranes) just as the cell membranes are moist for the same actions to take place.

Question 4: The dialysis tubes lying side by side are similar to cell membranes because they are moist and they allow small particles to diffuse. They are different because the only method of material passage is diffusion.

Question 5: In local signaling, cell membranes are in direct contact with each other. Cellular environment effects movement of various particles. Cell membranes have protein channels and allow materials to be moved across the cell membrane, and they are moist to allow for diffusion. The dialysis tubing is a model for the diffusion portion of the cell activity.

Question 6: Examples include neurotransmitters in the synapse, antigens triggering antibody response, target cells responding to specific hormones, and many others.

Resources:

- Selective Permeability of Dialysis Tubing Lab Explained: https://schoolworkhelper.net/selective-permeability-of-dialysis-tubing-lab-explained/
- Diffusion, Osmosis and Activ Transport: Fuse School https://www.youtube.com/watch?v=PRi6uHDKeW4
- Diffusion; Kahn Academy: https://www.youtube.com/watch?v=a_Y9wBQ610o
- Diffusion and Osmosis; Kahn Academy: https://www.youtube.com/watch?v=aubZU0iWtgI
- Cell-Diffusion; CBSE9: https://www.youtube.com/watch?v=71MSBEwMGDA&t=83s

Part 2. Rescue Me: A Cell's Call for Homeostasis

Lesson Background: The following activity introduces students to cellular communication. In this activity, students will investigate the relationship between transmembrane proteins and the physical link they create between the extracellular matrix and the cell's cytoplasm. This activity correlates to Campbell's *Biology*, Chapter 11: Cell Communication (Pearson Education) which is the text I use in my class. The proteins reviewed are discussed in the book and the PowerPoint (links to PPT provided). This activity can occur after the PowerPoint or after the students read the chapter. An alternative to the chapter is to have them view the Kahn Academy's Cell Signaling series (link below).

Students will investigate how a change in the environment begins a chain of events that starts with the trigger, leads to a response of a receptor protein, information travels down a pathway and a response is produced to bring the cell back into a state of homeostasis. It is important that students understand that their cells are continually communicating with each other. Cells do this by sending and receiving chemical signals. This "molecular conversation" lets the body's cells coordinate their activities, which is very important in maintaining homeostasis.
Cells signal each other either by direct contact or by the release of a substance from one cell which is then taken up by another cell. This is where students should understand how the permeable membrane works and that not all materials can enter a cell.

Interactions at the cell membrane are very complex and result in a membrane nanostructure that regulates diffusion and mobility of membrane biomolecules. These effects are important regulators in cell signaling which governs basic activities of cells and coordinates multiple-cell actions. The ability of cells to perceive and correctly respond to their microenvironment is the basis of development, tissue repair, and immunity, as well as normal tissue homeostasis. The recognition that cell membranes exhibit nanoscale structures has had a profound impact on the study of cell signaling and membrane physiology.

The work of the cell and its tiny nanostructures (organelles) within it play key roles in maintaining life. The ultimate goal of our body is to maintain a constant state of balance known as *homeostasis*. In our bodies, the task of maintaining homeostasis is carried out by cell transport, moving molecules into and out of a cell. This phenomenon occurs across the outer covering of a cell, the plasma membrane. The membrane is *selectively permeable* meaning that it only allows select nano-sized molecules to move across it.

Materials:

- Environmental Response Cards
- Cell Communication PowerPoint

Prerequisite: Students should have some understanding of signaling pathways. While many of the pathways are very detailed and complex, these examples are common and should provide an entry point into examining reception, transduction, and response of cells.

Advanced Preparation and teaching tips:

- Cards can be printed on different colors. Laminate for reuse.
    - Environmental changes in one color, proteins in one color and the response in one color.
- Students could also be asked to circulate without talking.
- Students can look at the different colors for a response.
- All proteins are the same color to represent the specificity of the protein, but their response based on the cell is different.

Directions for the Activity:

1. Randomly lay out printed cards on student desks, face down.
2. As an opening, teacher can either introduce cell communication, or can review concepts.
3. After the review, have students turn over the cards that are on their desks. At this time, have students spread out around the class.
4. When you yell "GO," students should call out what's on their card and search for the "environmental change," the "protein" that recognizes the change, and the "response." Students should continue to call out until their pathway is complete.
5. Once complete, students will share their pathway and record on their student sheet.

Variations:

The "noise" represents the various signals that are constantly bombarding the system at all times. Proteins are specific and reception depends on the receiver, so while there are a number of proteins circulating, they only work because of their specificity.

Answer Key for cards:

Environmental Change	Protein	Response
Ouch! You cut your finger	Fibronectin	Plays a major role in the formation of blood clots
Time to Divide!	Fibronectin	Cellular adhesion to the ECM
My blood sugar is low!	Insulin	Regulates blood sugar
Help! I can't breathe!	Epinephrine	Smooth muscle contraction
It's a Bear!	Epinephrine	Fight or Flight response
Puberty	Testosterone	Increased bone density
Puberty	Testosterone	Growth of body hair
Achoooo!	Histamine	Increased vascular permeability
Time to wake up!!	Histamine	Increase wakefulness

Follow-Up: Once activity is completed, as a homework assignment, students should trace the pathway for each event.

Resources:

PowerPoints:

- Pearson Education: Biology by Neil Campbell and Jane Reece: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=8&ved=2ahUKE

wjX_dq07f7oAhWjna0KHZBNAKQQFjAHegQIAxAB&url=http%3A%2F%2Fwww.bville.org%2Ftfiles%2Ffolder5403%2Fap%2520bio%2520cell%2520communication%25202015%2520Chapter_11_Cell_Communication%2520%25283%2529.ppt&usg=AOvVaw2_UiqCFkr0BZ8Ejd0B2OaM

- Cell Signaling and Communication between Cells: www.slideshare.net/vishwanth555/cell-signaling-16936890
- Cell Communication Chapter 11 for Biology Campbell and Reece: https://www.slideshare.net/veneethmathew/11-lecture-cellcommunication
- Cell Communication; Houston Community College https://learning.hccs.edu/faculty/wendy.sera/biology-i-1306/lecture-powerpoint-presentations/chapter-11-powerpoint-3-slides-per-pg

Cell Signaling:

- Cell Signaling: https://en.wikipedia.org/wiki/Cell_signaling
- Introduction to Cell Signaling: https://www.khanacademy.org/science/biology/cell-signaling/mechanisms-of-cell-signaling/a/introduction-to-cell-signaling
- Kahn Academy Cell Signaling: https://www.khanacademy.org/science/biology/cell-signaling

Next Generation Science Standards:

- HS-LS1-1.A Structure and function
- HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

Crosscutting:

- HS-LS1-3 Stability and change

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