Berkeley Engineers and Mentors

UnbelievaBUBBLE

Target Grade: Elementary/Middle School
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Brief Overview

This lesson teaches mentees about the properties of bubbles, including their tendency towards spherical shapes, how to calculate their volume and surface area, how they're created, and their connection to the cell and the phospholipid membrane. In fact, we'll be using bubbles as a model to learn about the cell membrane and its properties. The students will learn concepts such as surface tension and the nature of cell membranes through making their own bubbles and manipulating their size and shape.

Teaching Goals

After this lesson, students should understand the following concepts and terms:

- Definition of a **bubble**: a thin layer of liquid enclosing a gas, often spherical in shape
- **Surface tension**
  - A property of liquids—the tension on the surface caused by the attraction of the surface particles by the rest of the liquid below that minimized surface area
- Area vs. volume
  - **Area:** two-dimensional surface measurement of an object
  - **Volume:** three-dimensional spatial measurement of an object
    - Optional: formulas for surface area and volume of sphere for older sites
- Nature of cell membranes: structure of **lipid bilayer** (aka **phospholipid bilayer**)
  - Application of surface area and volume
  - **Semipermeable** nature of cell membrane
    - Optional: introduction to fluid mosaic model

Careers and Applications

Bubbles are often thought of as a common child's pastime, from blowing bubbles outside using store-bought bubble solution to enjoying the bubbles created by automatic bubble blowers. There is, however, much more to bubbles than what might initially come to mind. Common occurrences of bubbles that can be seen in daily life include the bubbles that form in carbonated drinks such as soda or sparkling water, water vapor from boiling water, and detergent bubbles. Another example is a spirit level, which is a tool used to determine whether a surface is level. The curved vial in a spirit level is mostly filled with a liquid and contains a bubble, which rests in the center at the highest point and moves away from the center of the tube when resting on an inclined plane. Bubbles are also seen in the gas released from chemical reactions, such as that between baking soda and vinegar.

Extending the topic to the cell membrane, the properties of the phospholipid bilayer are conducive to research in curing diseases as we can study the specificity of protein channels and the gene sequence coding for cell membrane receptors. One of the many applications of study on the cell membrane is cancer research, and more information can be found here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2938092/#targetText=Membranes%20play%20a%20critical%20role,cytoplasm%20and%20the%20extracellular%20environment.

Agenda

- Introduction
- **Module 0:** What Are Bubbles Anyway? (5 min)
- **Module 1.1:** Introduction to the Lipid Bilayer (5 min)
- **Module 1.2:** Bubbles Inside Bubbles (10-15 min)
    - Optional surface area and volume calculations
- **Module 2:** All Shapes and Sizes (10-15 min)
- **Module 3:** Adventure into the Cell (10-15 min)
- Conclusion

Introduction

To begin the lesson, bring up the topic of bubbles and ask the students what they think makes up bubbles (air surrounded by a thin film, often consisting of a soapy liquid). Where are bubbles found in everyday life? Provide examples from Careers and Applications if you'd like.

Figure 1: Girl blowing bubbles

Module 0: What Are Bubbles Anyway?

Introduction

We've all probably been exposed to bubbles from a young age, but what exactly is a bubble and how do they form? What is the surface of a bubble made of? Let's explore what makes up a bubble and go from there.

Background for Mentors

The definition of a **bubble** is simple: it consists of air surrounded by a liquid film, often in a spherical shape. The surface of a bubble is composed of three layers—two **hydrophobic** (nonpolar) soap layers surrounding a **hydrophilic** (polar) water layer. As we'll see later, this is analogous to the

Figure 2: Structure of bubble surface

structure of the phospholipid bilayer of the cell membrane, which has polar heads and nonpolar fatty acid tails. The soap molecules in a bubble are oriented with their hydrophilic heads facing towards the water layer and their hydrophobic tails facing away from the water layer, towards the outside environment. A bubble will try to assume a spherical shape, as the sphere minimizes the surface area of the bubble and is thus most energetically favorable.

Teaching Goals

- Introduction to spherical shape of bubble
  - Important since there are also exceptions
- Surface tension and its effect on shape
  - Surface tension is an important property of water and helps water molecules stick together
  - The addition of soap decreases the surface tension and forms a thin flexible skin that can encapsulate air, thus swelling into a spherical shape

Materials

- Store bought bubble solution (1 bottle per site)
- Several assorted bubble wands (3-4 per site)
- Paper towels (1-2 rolls per site)

Procedure

1. This is meant to be a short demo to spark interest in the students for bubbles.
2. Tell the students beforehand to not run after the bubbles, but they can touch and/or pop them if they'd like.
3. Discuss the shape a bubble typically takes: individual bubbles tend to form spherical shapes. This is because the surface area of a sphere is minimized and is thus most energy efficient. Soap decreases the surface tension of the solution and the film clings together to form a sphere
   a. As an analogy, say someone has a pillow for which they need to knit a pillowcase. It would be most efficient if they made the pillowcase just the right size to fit the pillow instead of a larger size, since that would be a waste of material and energy.
   b. Similarly, for a given volume of air, the walls of the bubble will form a spherical shape since a sphere has the smallest surface area to cover a given volume.
4. At the front of the class, use bubble wands to blow bubbles towards the students, noting to the students that the wands can create varying sizes of bubbles.


Figure 3: Bubbles

5. Note that individual bubbles are round.
6. If the students want to blow bubbles as well, let them know that they'll have the opportunity very soon.

Additional Notes for Mentors

To keep this module from becoming unnecessarily messy, it's prudent to keep paper towels on hand and be careful with where the bubbles are blown. Make sure to keep the bubble solution in the hands of a mentor at all times during this module.

Module 1.1: Introduction to the Lipid Bilayer

Introduction

The lipid bilayer is a double layer and is the basis for cell membranes as well as many organelle membranes. In this module we'll be going over the structure of the membrane using an interactive demo! Hopefully through a visual representation, the students can gain a better understanding of the structure of the membrane and the liquid in between the two layers of phospholipids. We'll also be introducing the connection between bubbles and the membrane. Bubbles are not perfect models for the cell, but we'll learn about similarities between the two.

Background for Mentors

The **lipid bilayer**, also known as the **phospholipid bilayer**, is a thin polar membrane composed of two layers of lipid molecules. It can be seen as the universal basis for cell membrane structure, as lipid bilayers comprise the membranes of cells and most organelles (e.g. nucleus, mitochondria, chloroplasts, etc.). The lipid bilayer separates the insides of a cell from the outside environment and is **semipermeable** so that only certain materials can pass through (such as nutrients and oxygen in and waste products out). This is a critical feature for ensuring the survival of cells and allowing regulation of metabolic processes. More on the cell membrane will be explained in the last module.

Teaching Goals

- Structure of phospholipid bilayer
    - Polar heads and nonpolar fatty acid tails
- Semipermeable nature of membrane
- Connection between bubbles and bilayer:
    - Both have double layer surrounding liquid

Materials

- Premade bilipid membrane demo
    - 1 container (plastic or mason jar)
    - Polar heads
        - 6-8 play doh balls
        - 6-8 styrofoam balls
    - Nonpolar tails
        - Toothpicks
- Water (obtained at site)

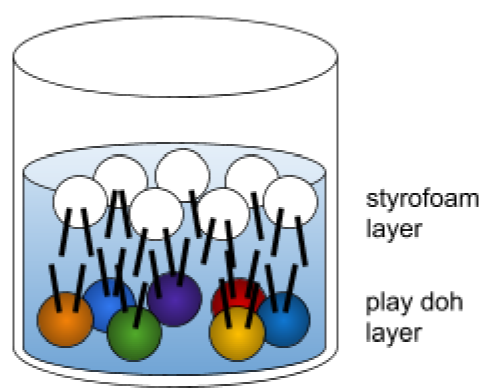


Figure 5: Lipid bilayer model

Procedure

1. This is meant to be a quick demo to demonstrate the structure of the double membrane, which is seen in the cell membrane as well as in bubbles.
2. The model initially consists of styrofoam balls and clay balls with straws sticking out in a V shape. The balls represent the polar heads of the phospholipid molecules and the toothpicks the extending fatty acid tails.
3. The balls are all on the bottom of the container in the beginning, but after adding water the styrofoam balls will float and the clay balls will sink.
    a. Position the straws so that they point towards each other (as shown in the diagram).
4. Add enough water so that the styrofoam balls float to the surface and the clay balls sink to the bottom of the container (about halfway to the top of the container).
5. The “phospholipids” stay on their respective positions (top and bottom) even when slightly agitated. The water represents the space between the two phospholipid layers. Both sets of “phospholipid heads” can shift and have gaps between them, so explain that smaller objects would be able to pass through the layers but larger objects would not fit as a model for the semipermeable nature of the membrane.
6. Explain to the kids that just as cell membranes have hydrophobic and hydrophilic layers, bubbles do as well! Bubbles are rather similar to cell membranes in this regard.

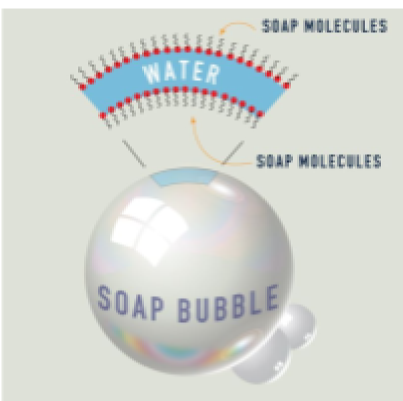


Figure 2: Structure of bubble surface

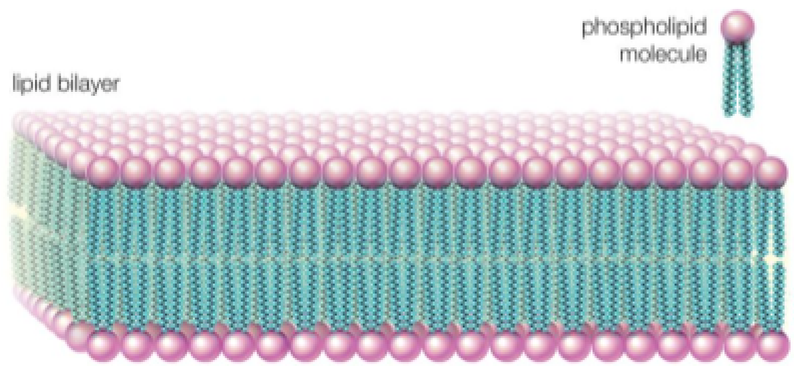


Figure 4: Diagram of phospholipid bilayer

Additional Notes for Mentors

Please pour out the water after this demo and dry off the play doh as much as possible to be reused in the future. Be careful that the students don’t pour out the water or deform the Styrofoam or play doh.

Module 1.2: Bubbles Inside Bubbles

Introduction

Bubbles tend to pop easily, but if we’re careful, we can keep bubbles intact for longer and even blow bubbles within bubbles. As a fun fact, the feat of creating the most soap bubble domes inside each other is actually a Guinness World Record, believe it or not! Su Chung-Tai from China blew an incredible 15 soap bubble domes inside one another other back in 2012. That’s pretty incredible, to say the least. Let’s see if anyone can make a new world record today!

Background for Mentors

As mentioned in Module 0, the film of a bubble is made of three thin layers: soap, water, and another layer of soap, in that order. Bubbles pop when the water between the layers of soap evaporates. Adding glycerin to the bubble solution makes the soap film thicker and stronger, and thus the water doesn't evaporate as quickly and the bubbles can last longer. The increased strength also means that the bubbles can be blown to a larger size. For better bubbles, it's also important to use water with as few impurities as possible to keep the bubbles from popping for a longer time, so distilled water is preferred to regular tap water, but regular water also works well.

Blowing a bubble inside causes the outer bubble to expand to accommodate the bubble within. The air blown into the inner bubble not only increases the volume of that bubble, but also increases the volume contained in the outer bubble. This also occurs for any additional bubbles blown inside the first original bubble. The elastic bubble surface allows an increase in volume to an extent. It is possible to find the approximate volume of the bubble(s) blown by measuring the diameter of the bubble outline left behind after the bubble pops. The smaller bubbles inside can be thought of as analogous to organelles, the specialized structures inside a cell (e.g. nuclei, mitochondria, vesicles, lysosomes, etc.). The cell needs to increase in area to accommodate the volume of the organelles within, which is similar to the fact that air blown into inner bubbles increases the size of the outer bubble.

An important application of surface area and volume applies to the size of cells. Cells need to transport materials through their membranes; namely useful materials in and waste products out. As the size of a bubble increases, however, the volume increases faster proportionally to the surface area. Mathematically, this makes sense as the radius in the surface area equation is squared while the radius in the volume equation is cubed, as will be described in the Introduction to Area and Volume section later. Thus cells cannot sustain themselves by means of efficient transport across the membrane when they become too large. It's true that bubbles are not cells and do not need to transport materials across their surfaces, but bubbles can be used to visualize this concept. Larger bubbles are more fragile and prone to popping.

Teaching Goals

- Spherical shape of bubble
- Surface tension
- Relationship between area and volume
    - Optional: equations for area and volume

Materials

- 1 cup liquid dish liquid
- 6 cups water (obtained at site)
- 1 tb glycerin
- Bucket to mix
- Medium cups (1 per group of 3-4 students)
- Straws (1 per student)

Important Note

It's true that the lipid bilayer doesn't seem to relate to bubbles, so the jump from the previous demo to making bubbles may not be intuitive. Bubbles are, however, in certain ways rather similar to cell membranes, which are composed of lipid bilayers. The surface of a bubble and the cell membrane are both fluid, flexible, and can perform self-repair (after limited disturbance).

Procedure

1. To make the bubbles we'll need a bubble solution, so let's begin with making that.
2. Mix the dish soap, water, and glycerin thoroughly in the bucket.
3. Scoop ~ ½ cup for each group of students.
4. After making the bubble solution, have a mentor pour some liquid carefully on the table for each student and let the liquid spread out into a thin layer.
5. The students will dip the end of the straw in bubble solution, and then place the tip of the straw vertically into the solution and blow a bubble to a medium size.
   a. It's important not to blow the bubble too large at this step, since the soap film may not be strong enough to stretch enough to accommodate bubbles inside.
6. When satisfied with the size of the first bubble, remove the straw slowly from the bubble.
7. Dip the straw again in solution, then carefully insert it through the membrane of the bubble and into the solution on the table. Blow steadily to form another bubble.
8. If desired, repeat steps 5 and 6 until they have formed as many bubbles as they'd like.
9. Make sure the students keep straws and the cups!
10. Keep the remaining bubble solution by pouring it back into the bucket.

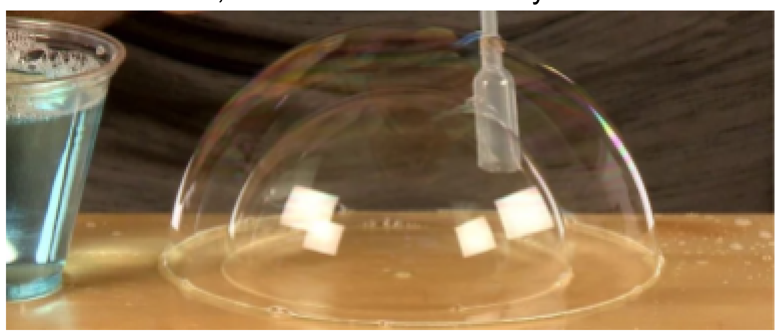


Figure 6: Bubble in a bubble

Introduction to Area and Volume (formulas are optional)

- **<u>The specific calculations of this section are geared towards more advanced students, but it would still be a good idea to go over the concepts of area and volume with students of all ages.</u>**
- For younger sites, it's sufficient for them to compare the outlines of differently sized bubbles after the bubbles pop. Larger bubbles leave larger outlines than smaller bubbles and thus have more surface area.

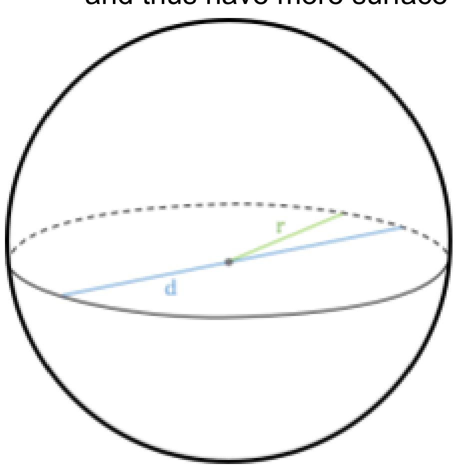
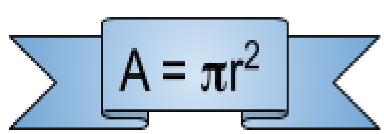


Figure 4: Labeled diagram of sphere

- As the students are blowing their bubbles, discuss the increasing volume of the bubbles. Is there a way we can figure out the volume of the bubble?
- Specifically, how does the volume of a sphere increase with area? Ask if anyone has any suggestions.
- **Area:** 2D surface measurement
- The cross-sectional area of the bubble at its largest point can be calculated after it pops by measuring the diameter of the bubble outline on the surface and then calculating using the area formula:



$$A = \pi r^2$$

        - As the formula uses the radius and not the diameter, it's important to **divide the diameter of the bubble by 2** before substituting the radius into the equation.
- The area formula above calculates the area of a circle, which is the cross section of a bubble. To find the **surface area** of the sphere of an entire bubble, use the following formula for surface area of a sphere:

$$A = 4\pi r^2$$

- Potentially discuss the volume (for a sphere) formula with older students:

$$V = (4/3)\pi r^3$$

    - **Volume:** 3D spatial measurement
        - Make sure they realize that the volume calculated would be for the entire sphere/bubble and that the bubbles they blew were half-spheres!
        - To calculate the accurate volume for the half-spheres they created, it is necessary to divide the volume found for a sphere by two.

Additional Notes for Mentors

To successfully blow bubbles within a bubble, the original bubble needs to be large enough to encompass the bubbles within, since otherwise the film of the outer bubble will not be able to stretch adequately. At all stages of the module, the bubble must be blown slowly and carefully as to not pop the outer bubble(s). It can get a bit messy, so try to make sure not to pour too much solution on the table and then keep paper towels on hand to help wipe up any messes.

Module 2: All Shapes and Sizes

Introduction

Contrary to popular belief, not all bubbles have to be spherical! It's true that when bubbles are isolated, such as when they're floating in the air or suspended in a carbonated drink that they all take on spherical shapes, but with the use of external structures, it is possible to create bubbles of different shapes and orientations.

Background for Mentors

Let's first discuss in more detail the reason why bubbles tend to form spheres in the first place. Bubbles are round since spheres are the most energetically favored shape due to the minimization of surface area. However, when there are multiple bubbles, the situation is different, though the driving force behind the shape of the bubbles is still to minimize surface area. For example, when two bubbles of the same size

Figure 7: Hexagonal Bubbles

meet, the film between them is flat. When the bubbles are different sizes, the smaller bubble will seem to bulge into the larger bubble. When enough bubbles are in contact with each other, they meet to form walls at an angle of 120° and thus form hexagonal shapes (see picture at right). When bubbles are formed around other solid objects, they mold themselves around the surface and can assume non-spherical shapes.

Teaching Goals

- Surface tension and effect on shape
    - Individual bubbles are spherical but this changes when bubbles are in contact with bubbles or other materials)
- Area and volume

Figure 8: Possible 3D Structures

Materials

- Straws (cut in half)
- Masking tape (2 rolls *per site*)
- Bubble solution made earlier
- 1 bucket *per site*

Procedure

1. We will be building structures around which the bubbles will form. This way, we will be able to create bubbles of different shapes and sizes!
2. There is a variety of three-dimensional shapes that can be created with the straws (see right for references), and these shapes can form differently shaped bubbles!
3. The students can make structures as simple or complicated as they'd like, and encourage them to be creative with their designs. Adding more straws on the insides of structures can form beautiful frameworks.
4. Have a mentor combine all of the previous bubble solutions inside the bucket. The students can then take turns dipping their structures inside the solution and observing the bubbles formed.
    a. What shapes are the bubbles? Why do they take on these shapes?
        i. The driving force behind the bubble shapes is still minimization of surface area as to decrease the energy needed to expand the film of the bubble to that size, and the bubbles will form around the straw foundations.
5. The previous formulas for area and volume no longer work. Why?
    a. The bubbles are no longer perfectly round. For older sites, discuss why the volume is now smaller relative to the surface area of the bubble surfaces (spheres maximize the volume to surface area ratio).
6. After the students observe the shapes of the bubbles in the straw structures, they can blow to release the bubbles into the air. They magically resume their spherical shapes when separated!
    a. The films are flexible and instantly adjust to the formation with the least energy.

Additional Notes for Mentors

It might become hectic if students all want to test their structures at once, so if some students finish building earlier they can use the bubble solution first. As before, keep paper towels handy!

Module 3: Adventure into the Cell

Introduction

The bilipid membrane of the cell is flexible and **semipermeable**, which means that the membrane allows only certain substances to pass through, usually smaller molecules or solvents (liquids). We'll apply what we've learned about bubbles, especially volume and area, to learn about some basics of cells.

Background for Mentors

Bubbles can be used to simulate a cell membrane in several different ways. Similar to how only certain substances can pass through the membrane of a cell, it's possible to pass items through a bubble membrane under certain conditions! Remember when the students were able to insert straws into bubbles in a previous module to blow bubbles inside a bubble? The trick to pass an item through a bubble surface is to first wet the object and then move slowly. A bubble pops when the water trapped between the soap layers pops, so if the item moving through the surface is wet, the bubble should not pop. We'll use this concept to model channel proteins in membranes. Just a reminder that we first covered the structure of the phospholipid bilayer in the first module and then discussed the relationship between surface area and volume.

Cell membranes are highly specific as to what types of substances can pass. For example, small nonpolar molecules can pass quickly, water can pass slowly, and large molecules such as glucose and charged molecules such as sodium have a very hard time crossing the membrane or cannot cross at all. But what happens if the cell needs to take in a molecule that's too big to come through the membrane? Other than processes including endocytosis and active transport, there are **protein channels** that span the cell membrane and allow various materials to pass.

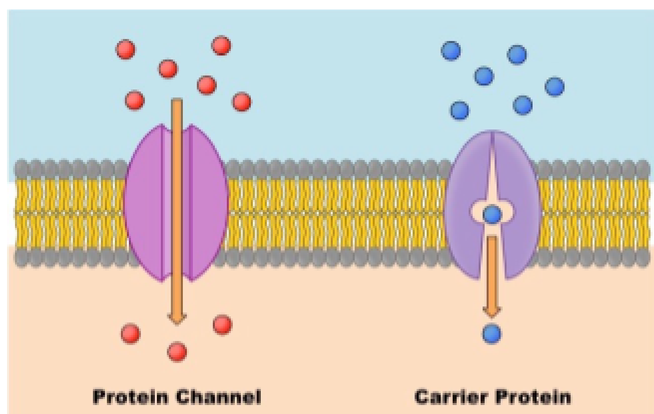


Figure 9: Transport across the membrane

Protein channels are embedded in the cell membrane and provide a hydrophilic pathway (as opposed to the hydrophobic interior of the phospholipid bilayer), especially for water and charged ions. Each channel protein only allows specific molecules to cross. There are also different types of channel proteins, such as non-gated, voltage-gated, etc. For more information, check out this publication about membrane transport:

https://www.ncbi.nlm.nih.gov/books/NBK26815/#targetText=There%20are%20two%20classes%20of%20membrane%20transport%20proteins%E2%80%94carriers%20and,channel%20proteins%20is%20always%20passive.

Teaching Goals

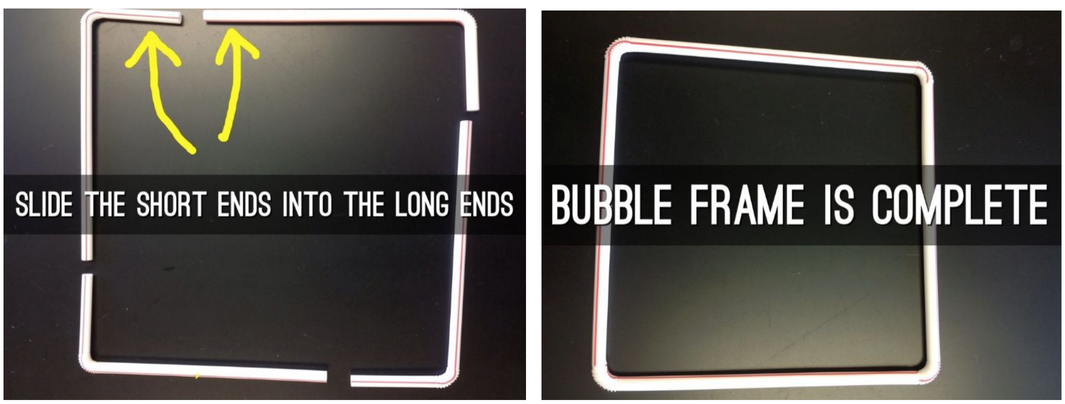
- Semipermeable nature of membrane
- Connection between film of bubble and cell membrane
- Concept of channel proteins (as modeled by “holes” in bubble membrane)

Materials

- Straws (4 per group)
- Thread
- Scissors
- Bubble solution (leftover from store bought okay)
- Objects to pass through bubble film

Procedure

1. For this module, we’ll be using a bubble film to simulate the membrane of a cell.
2. The films are made by first making a simple straw frame.



Figures 10 and 11: How to make straw frame

3. Then the frames are dipped into bubble solution to form a thin film.
4. Working in groups, the students will then experiment passing different objects through the bubble film. We’ll give them some of the leftover straws to use, and then they can use certain small objects to try, such as bubble wands.
    a. They can first try just passing dry objects through to contrast and confirm that they would pop the bubble film.
    b. Then they can dip the objects in bubble solution first and then pass them slowly through the film.
5. Have a mentor cut out a few 4-5 inches of thread and then tie the ends together to form small loops.
6. A student can gently dip the string in bubble solution and then place the loop in the film. The string should stay in the bubble film.

7. Now the fun part. Use a dry straw or finger to pop the film between the loop of string. The outside bubble membrane should remain intact! The loop of string models a channel protein, as it opens a passageway through the “cell membrane”. The students can try poking a finger through the hole created, modeling passage into the cell.

Additional Notes for Mentors

Make sure the kids don’t try to use objects that shouldn’t get wet! Examples may include electronics such as watches and phones. This module might also get messy so keep paper towels readily available.

Conclusion

Bubbles are really fun to make and play with, but the science behind bubbles is just as fascinating! Hopefully the students learned more about the formation of bubbles and their properties, including the effects of surface tension on bubble shape and the applications of surface area and volume. Though bubbles and cells may seem very different, it’s interesting to think of bubbles as modeling certain aspects of the lipid bilayer, including the concepts of semipermeability and the double layers!

References

- https://docs.google.com/document/d/1xPbR0ZAljEIA6Xk9cfh1GWcRHTpSRaw-n26_NOd39RA/edit?usp=sharing

Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Storebought bubble solution	1 per site	$27.90 for 24 total $13.95 for pack of 12	https://www.amazon.com/Joyin-Pack-Bubble-Assortment-Dozen/dp/B01FI4GSLM/ref=sr_1_1?keywords=bubble+solution+individual&qid=1568011413&s=toys-and-games&sr=1-1
Assorted bubble wands	3-4 per site	n/a	Inventory
Paper towels	1-2 rolls per site	$37.98	https://www.amazon.com/Essential-Multifold-01804-Fast-Drying-Absorbency/dp/B001AZKS4W/ref=sr_1_28?keywords=paper+towels&qid=1570068670&s=gateway&sr=8-28
Dish liquid	1 cup per site	$27.92	https://www.amazon.com/Dawn-Ultra-Dishwashing-Liquid-Original/dp/B079J67GL7/ref=sr_1_3_sspa?fpw=pantry&keywords=dish+liquid&qid=1569169541&s=pantry&sr=8-3-spons&srs=7301146011&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzNlAyWDIxQzZGWjZTJmVuY3J5cHRlZElkPUEwNzUwNTA3NkNWMFRDVTRPWE9HJmVuY3J5cHRlZEFkSWQ9QTAzODQ2MThGVzlHTlZER0wyWFgmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl
Glycerin	1 tb per site	n/a	Bechtel

Buckets	1 per site	n/a	Inventory (from Evan's lesson)
Play doh	6-8 balls per site	n/a	Inventory (from Evan's lesson)
Styrofoam balls	6-8 balls per site	$9.99	https://www.amazon.com/Pack-Foam-Balls-Polystyrene-Christmas/dp/B079FRNY4Z/ref=sr_1_4?keywords=styrofoam%2Bballs&qid=1570071375&s=gateway&sr=8-4&th=1
Straws	1 per student	n/a	Inventory
Scissors	2 pairs per site	n/a	Inventory
Tape	2 rolls per site	n/a	Inventory
Rulers	2-3 per site	n/a	Inventory
Gloves	2 pairs per site	$14.99	https://www.amazon.com/ProCure-Disposable-Nitrile-Gloves-Ambidextrous/dp/B07DRQK1N5/ref=sr_1_9?keywords=gloves&qid=1570156913&sr=8-9
Thread	1 roll per site	n/a	Inventory