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Bubble Lab Exercise

Peter Beltramo
University of Massachusetts Amherst

UMASS STEM-ED From Soap Bubbles to Cell Membranes Workshop

Bubble Lab Exercise- Introduction & Setup

Summary: The cell membrane is a ubiquitous component in mammalian cells which control many vital biological functions. It consists of a phospholipid bilayer with embedded protein molecules which serve to transport molecules between the interior and exterior of the cell. Understanding what makes cell membranes so important and how they function requires concepts from physics, chemistry, and of course biology, but it is difficult to learn and conceptualize the structure and function of membranes due to their nanoscopic size and dynamic nature which can't be properly appreciated in a static textbook. This activity draws analogies between the chemistry and structure of soap films, which are essentially the inverse of the cell membrane, to create a macroscopic model that illustrates many important concepts in biology. Concepts emphasized include membrane fluidity, flexibility, amphiphilicity, passive/active transport, and membrane fusion/division processes. Using materials entirely available at a grocery store, students explore cell membrane structure and function using the more tangible and accessible soap film.

Materials Needed (per group):

- Newspaper or paper towels
- Shallow pan
- Plastic drinking straws
- Thick string
- Fine thread
- Soap mixture (900 mL water, 100 mL Joy/Dawn/favorite brand soap, 25 mL glycerin or corn syrup) *(Glycerin/corn syrup helps make extra-long-lasting bubbles)*
- Fun objects to pass through the film
- Rubbing alcohol
- Vegetable oil
- Plastic knife
- Scissors
- Black construction paper

Procedure:

1. Work in groups of minimum 2 people.
2. Pick up your materials (see list above).
3. Spread paper towels/newspapers on top of the table and floor around where you are working.
4. Follow the Assembly Instructions to complete your setup

Assembly Instructions

1. To make your bubble solution, mix dish soap and water in a 1:9 ratio, adding one tablespoon of glycerin to each gallon of solution (does not need to be exact). **Let the solution age at least overnight for the longest-lasting bubbles.**

2. Fill the pan with the soap solution to a depth of at least 1 inch.
3. Cut a piece of string that's approximately four times the length of the straw and another piece of string that's approximately three times the length of the straws.
4. Thread both pieces through one of the straws and the longer piece through the second straw.
5. Tie the ends of the string together to make a loop.
6. Make the straws and string into the shape of a rectangle, cut the excess string from the knot, and hide the knot inside one of the straws. The string that was three straw-lengths long is the handle and the knot does not need to be hidden.
7. **For the setup for part 3**, do the same as above except thread a 2.5 straw length piece of the small thread through one of the straws. Make a small loop with a second piece of thread and tie a knot with the other piece of thread so the thread goes through the loop.
8. Assign one person to be the soap film holder, and the other to explore how the film behaves (switch jobs as necessary).
9. Holding the frame by the handle, immerse into the bubble solution.
10. Gently lift up the frame until the bottom straw is slightly out of the solution and the straws are parallel to the tabletop. You should have a rectangular soap film between the straws, but if not try again!

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Bubble Lab Exercise- Activities

Part 1: Observation

- Holding the string handle of the membrane film holder, immerse it into the pan of soap solution. Raise it out of the pan and allow the excess soap to drip off. Hold up the soap film-filled membrane holder and do the following:
    - Look at the light hitting the film and the different colors
    - Gently twist the bottom and top straws
- What characteristics of the soap film do you observe and how do they relate to the cell membrane?

Part 2: Self-Sealing and Passive Transport

- Make another soap film and take a paperclip (or other fun object) and try to slowly insert it into the membrane.
    - Were you successful?
- Try again, but this time coat the paperclip with some of the soap solution.
    - Why were you successful this time? Why do you think the paperclip must be coated with soap solution in order to pass through the membrane?
- Depending on how messy you want to get, dip a finger in soap, or use the paperclip, and partially insert it into the film. Move it around. Take it out of the film.
    - What happens to the film when you remove your finger?

Part 3: Active Transport and Ion Channel Proteins

- Take the other film holder that has the thin thread. Form a soap film, then pop the inside of the thread circle with a dry object.
    - What happens to the thread circle once you pop it and why?
    - Can you make the paperclip cross the soap film without dipping it now?
    - Move the thread circle around by sticking your finger in the opening. What do you observe?

Part 4: Hydrophobicity/Hydrophilicity

- Make two cups, one with vegetable oil and one with rubbing alcohol and dip a paperclip in each.
    - Which molecule is able to coat the paperclip such that it is able to pass through the membrane and why?

Part 5: Cell Division

- Take a straw and dip one end in the soap solution. Hold it just above the surface of the soap solution and gently blow to create a bubble. Make a bubble about 3-4 inches across.

- Take a plastic knife (or paperclip), wet it with soap solution, and starting in the solution at one side of the bubble, cut the bubble in half. You have created a bilayer across the middle and made two bubbles.
    - Think about the configuration of molecules at the interface, what must happen for the bubble to divide?
- Cut the two new bubbles in half. Keep dividing the bubbles until you have at least 10.
    - Are there any spaces in between the bubbles or do they fill in all of the available space?

<u>Part 6: Cell Fusion</u>

- Use a straw to create a few bubbles in your soap solution. Coax the bubbles toward each other and try to get them to fuse into a single big bubble.
    - Think about the configuration of molecules at the interface, what must happen for the bubble to fuse?

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Bubble Lab Exercise- Post-Activity Questions & Answers

Part 1: Observation of Flexibility and Fluidity

- What characteristics of the soap film do you observe and how do they relate to cell membranes?
    - Fluidity: The theory of the structure of the cell membrane is called the Fluid Mosaic Model. This means that the membrane is made of a pattern of many small molecules that are moving around and shifting position. You should be able to see movement in the light pattern, demonstrating that the molecules of the film are constantly in motion.
    - Flexibility: A lipid bilayer is a fluid arrangement within which the molecules can move freely through the plane of the bilayer. They can reorganize themselves into almost any shape without losing the contacts that satisfy their mutual attraction. The soap bilayer is actually less flexible than a cell membrane because a cell membrane is supported on both sides, one side by the cytoplasm and the other by lymph or other tissue fluids. So, whatever you are doing to the soap film, plus more, can be done to cell membranes without breaking them.

Part 2: Self-Sealing and Passive Transport

- Why do you think the paperclip must be coated with soap solution in order to pass through the membrane? How come you can insert and remove your fingers without popping the film?
    - A cell membrane can repair or reform tears in its lipid bilayer, allowing it to stay intact, provided there is a source of phospholipids. Since the paperclip or your finger is coated with soap molecules, they can rearrange at the film interface to allow the soap film to repair and remain stable. Likewise, foreign objects can pass through the film when coated with excess molecules, much like small nonpolar molecules or lipid coated molecules may passively diffuse through the membrane without it breaking.

Part 3: Active Transport and Ion Channel Proteins

- What happens to the thread circle once you pop it and why?
    - Initially, the circular thread is disordered, but once the inside is popped it rapidly expands to form a circle. This is due to surface tension. The forces between the soap molecules are equal when they are in bulk solution, but when the new interface forms between the soap/thread and air there is a greater force pulling the interfacial molecules in towards the other parts of the film. This force pulls the thread in all directions, forcing it to maximize its overall area and become circular.
- Can you make the paperclip cross the soap film without dipping it now?

    - Larger molecules cannot pass through the cell membrane or soap film without some help. The only way these large molecules can get into the cell is through protein channels, which allow for a passageway through the hydrophobic region of the membrane which would otherwise block transport. This is an example of active transport, since the protein molecule needs to open and close to allow the cargo through, which requires external stimuli and energy. Protein ion channels can open/close due to chemical interactions (a molecule docking with the protein), photostimulation, ionic gradients, or also mechanical interactions (the membrane getting more tense).
- Move the thread circle around by sticking your finger in the opening. What do you observe?
    - This is another example of membrane fluidity. Just like the soap film molecules and phospholipid molecules are in constant motion along the membrane, the protein molecules also dynamically rearrange and move along the film. Sometimes protein molecules need to collocate, or come together, in order to initialize signaling processes.

Part 4: Hydrophobicity/Hydrophilicity

- Which molecule can coat the paperclip such that it is able to pass through the membrane and why?
    - Vegetable oil typically has a triglyceride structure that is very similar to the fatty acid tails of a phospholipid or soap molecule. Since it is "lipid-like", it serves as a good transport vehicle to help the paperclip easily cross the membrane. On the other hand, rubbing alcohol is a polar molecule that can only cross the membrane or soap film on a much longer time scale. In addition, the hydroxyl group can become charged, further hindering transport. In general, the film should pop when the rubbing alcohol is used as a coating material on the paperclip.

Part 5: Cell Division

- Think about the configuration of molecules at the interface, what must happen for the bubble to divide?
    - Cell division is somewhat similar to this process. Cells divide when an organism is growing, when tissues need to be repaired, or when the surface area to volume ratio becomes too small (i.e. the cell grows too large). This process requires energy because the soap molecules or phospholipids need to, temporarily, adopt an unfavorable state. Proteins help pinch the membrane at the center of the cell and also provide the energy to complete the division process.
- Are there any spaces in between the bubbles or do they fill in all of the available space?
    - The bubbles fit together without any spaces between them. Your cells fit together in much the same manner.

Part 6: Cell Fusion

- Think about the configuration of molecules at the interface, what must happen for the bubble to fuse?
    - There are circumstances in a cell where two membranes fuse into a single larger structure. Researchers study fusion to understand neurotransmission, and how drug delivery vehicles can be engineered to more efficiently cross the cell membrane by fusion. Like the previous example, fusion is an energy intensive process, meaning energy must be put into the system in order for it to occur. This is because the soap or phospholipid molecules must adopt unfavorable configurations in the intermediate stages before two bubbles combine into one. A class of proteins called SNARE proteins specifically initialize this process in the cell.

General Questions to think about

- What is the function of a cell membrane?
- Why are cell membranes important?
- Can you list at least three ways the soap film model is like a real cell and two ways it is different than a real cell structure?

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Bubble Lab Exercise- Useful Resources

Links:
https://vimeo.com/52263821
https://www.exploratorium.edu/snacks/cellular-soap-opera
http://blanchasscienceclasses.weebly.com/uploads/9/6/7/7/96774448/bio_cell_membrane_activity.pdf

Other soap film exercises:
https://www.exploratorium.edu/snacks/soap-film-on-can
https://www.exploratorium.edu/snacks/soap-film-interference