Bubble Membrane Model

SC Academic Standards: 6.L.4A; 7.L.3A; H.B.2A; H.B.2B; H.B.2C; H.B.3.

NGSS DCI: MS-LS1.A; HS-LS1.A.

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.6; S.1A.7

Crosscutting Concepts: Cause and Effect: Structure and Function; Systems and Systems Models.

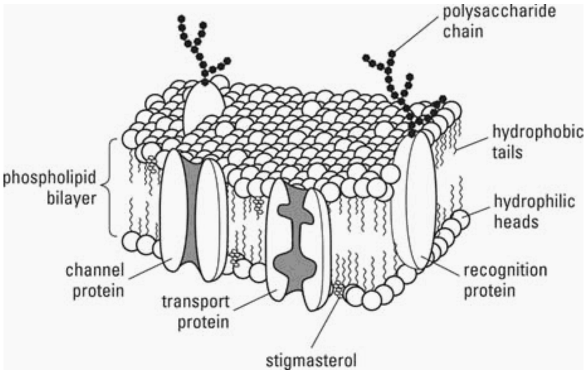
Focus Questions(s): How is a bubble film like a cell membrane? How do molecules get through a cell membrane?

Conceptual Understanding: Cells are the most basic unit of any living organism. All organisms are composed of one (unicellular) or many cells (multicellular) and require food and water, a way to dispose of waste, and an environment in which they can live in order to survive.

Transport processes which move materials into and out of the cell serve to maintain the homeostasis of the cell.

Background: Every cell in your body needs to take in nutrients, oxygen, and raw materials and to export wastes and other substances. But it's not just a random traffic jam! At the boundary of every cell is a cell, or plasma, membrane that regulates what comes in and what goes out of the cell. Plasma membranes consist of a phospholipid bilayer, with each molecule having a hydrophobic tail and a hydrophilic head – so the two lipid strands form a "sandwich with the tails in the middle and the heads facing both inside and outside of the cell. This bilayer is studded with proteins that move laterally within the lipid membrane (like ice cubes floating in a a bucket of water), and is called a "fluid mosaic". Some proteins, and some phospholipids, may also have small chains of carbohydrate attached (these generally function in cell recognition – how a cell tells if another cell is foreign, or "self"). Nutrients, respiratory gases, wastes and inorganic ions must all pass through a plasma membrane on their way into or out of a cell.

Plasma membranes are **selectively permeable**: some substances can easily enter and exit the cell (or be transported in/ out of cells) and others cannot pass without assistance from the embedded proteins. In general, small molecules will **diffuse** *down* a concentration gradient (move from the side of the membrane with a high of a particular molecule to the side of the membrane with a lower concentration).



*stigmasterol in plants, cholesterol in animals

http://www.cliffsnotes.com/sciences/biology/plant-biology/energy-and-plant-metabolism/membrane-structure

Molecules often have a **net direction** of diffusion until the concentration of that molecule is equal on both sides of a membrane - at which point, the molecules are still diffusing, but there is no net *directional* movement.

Substances that are most like phospholipids easily pass through it (this includes non-polar molecules), as do very small molecules like CO_2 gas. Substances unlike the phospholipid membrane (usually polar molecules), and very large molecules, can cross the plasma membrane only with assistance from protein "channels" – these "channels" are not always open (they may be "gated") or may be specific to certain types of molecules (such as a glucose transport protein which only allows glucose through, or a Na+/K+ pump protein which allows Na+ and K+ through, though in opposite directions usually.

Sometimes a larger molecule, or a polar molecule, can't diffuse unless there is a protein "channel" in the membrane that it can move through (and sometimes these channels are blocked, or "gated", which might cause a gradient to be maintained). Facilitated diffusion is when a molecule diffuses (*down* the gradient) through a protein channel. Cells can also *create* concentration gradients by pumping some molecules *up* a concentration gradient, from the side of the membrane with least concentration to the side with a higher concentration of a particular molecule - this is done by **active transport**, also through proteins embedded in the phospholipid bilayer.

Interestingly enough, the disease cystic fibrosis is caused by a defect in the protein that acts as a channel for chloride ions to pass through the plasma membrane of certain cells in the respiratory tract- because of chloride ions aren't transported appropriately, thick plugs of mucus block the airways and infected individuals are prone to bacterial infections here.

In this lab we will explore a model of a cell membrane. A **model** is a simplified representation of a complex biological structure or process. A model focuses on a few key features in order to help us understand a biological structure. Because a model is simpler than the biological structure it represents, a model does not demonstrate all the features of the actual biological structure. You will use the model to help **explain** how a cell membrane works.

Materials: Bubble solution in a large plastic tray or aluminum cake pan, 2 drinking straws, scissors, 2 clothespins or pencils, string (one piece knotted in a loop, another piece strung through 4 (1/2 size) drinking straws, with a little slack, to make a square), black construction paper. To make your own bubble solution, mix 2/3 cup dish detergent with 1 TBS glycerin per gallon of water. Let the solution age overnight (at least).

Previous Knowledge: (biology): Plasma membranes are **selectively permeable**: some substances can easily enter and exit the cell (or be transported in/ out of cells) and others cannot pass without assistance from the embedded proteins. In general, small molecules will **diffuse** *down* a concentration gradient (move from the side of the membrane with a high of a particular molecule to the side of the membrane with a lower concentration).

Procedure: Divide into groups of 2-4 students. Once student will hold the soap film, the others can manipulate it and watch how it behaves. (Note: you may want to have the sting/straw squares made ahead of time).

1. Cut the straws in half with the scissors, so you have 4 halves.
2. Thread the string through the straws, leaving about 2 cm slack between each straw, then knot the ends to make a square or rectangle. Any leftover string can be used to make a handle to hold the frame by (think of a triangle atop the square). This is your bubble frame. You should still have one more piece of string, knotted so there is a half dollar size circle in the middle.
3. Holding the bubble frame by the handle, immerse the entire frame in your soap bubble solution.
4. Lift the frame up by the handle until the bottom half is slightly out of the solution (but over the pan to avoid dripping on floors) and the top straw is parallel to the table top. You should have a rectangular soap film between the half straws. If there isn't a soap film, try immersing it again.
5. Can you turn the 2 dimensional soap film into something more three-dimensional, or make a right angle? Try.
6. Wet your finger with the bubble solution. Gently poke it through the soap film. What happens? Can you move your finger around in the film? Now wet your finger with plain water and poke it into the film. What happens now?
7. Try gently poking a dry finger through the film. What happens now?

8. Make a new film on the frame. Can you and your partner, with the materials provided, figure out a way to get a pencil (or a clothespin) through the soap film without it either getting wet or popping the membrane?
9. Hold the bubble membrane up to the black construction paper – see how colors seem to swirl – this is an example of iridescence, which is caused by the interference between the light waves reflecting off the back surface of the soap and those reflecting off the front surface. The slight offset between the two sets of light waves is approximately equal to one wavelength of light and so when combined some wavelengths (or colors) are cancelled out, while some are strengthened. The colors change as the thickness of the soap film changes (which changes the amount of offset between the two sets of light waves).

<u>Extensions:</u> You can also try using plastic curtain rod holders instead of the ,knotted loop of string - wet it with bubble solution and insert into your film, popping any film that remains inside of the curtain rod holder. Then try getting something plastic and round, like a film canister with bottom cut out - so you have different sizes of "channel proteins". This can be used to explain the specificity of some transport proteins - some things will fit through the curtain rod holder but won't fit through the smaller film canister. Again, if the round plastic hoop objects aren't wet they will pop your membrane film.

Another extension is trying to blow bubbles inside of bubbles - pour some bubble solution into a tray, then make a bubble and set it on top of the solution (it will be like a bubble dome). Using a completely bubble-wet straw, stick the straw into the bubble dome and blow a new bubble, inside the first. You can also try putting something sharp inside the bubble – the trick is, make sure it is completely covered in bubble solution first before sticking it into the bubble.

<u>Reflection Questions:</u>

- **Based on your observations, what conditions allow objects to move through the soap membrane without popping it?** (non polar, like the phospholipid bilayer - really, the phospholipid bilayer is both polar and non-polar - the tails are non-polar and the glycerol heads are polar.)

What conditions cause the membrane to pop? Do you think the flexibility of the film influences its ability to resist popping? (anything dry caused the bubble film to pop. Soaking the string or film canister in bubble solution first, then putting it into the film allowed you to maintain the integrity of the film. If an object is wet it often will not pop a bubble. This is due to surface tension. Surface tension forms a thin "skin" on the surface of any liquid. This is why bubbles like landing on wet surfaces like a damp sponge or a wet hand. The surface tension of the bubble joins up with the surface tension of the wet landing surface. A dry landing surface breaks the surface tension of the bubble and it pops! Dirt and oils on your hands can also break-up the surface tension of a bubble. That is why it is easier to catch a bubble with a sock on your hand.

What types of substances do human beings need to take in / eliminate from their bodies? Do individual cells need to do similar things? (we take in food, gases, water - and eliminate water, gases, waste products like urea, excess vitamins. Yes, individual cells need gases and nutrients, and to get rid of wastes).

- **Can you think of examples where water moves across a membrane?** (in the urinary system, the nephron has portions that are permeable to water and portions that are not permeable. In the permeable portions, water gets reabsorbed across the nephron into the bloodstream).

- **What roles do diffusion and osmosis play in the transport of materials across a plasma (cell) membrane?** (diffusion is for gases and smaller molecules – large molecules can move across a membrane by facilitated diffusion, using a transport protein. Cells will try to more molecules to lessen a concentration gradient - but if the cell membrane is not permeable to the molecule, then diffusion and / or osmosis will not take place and the gradient will be maintained (or strengthened (increased), by active transport). Nerve cells, for example, use active transport of sodium and potassium to create a Na+ / K+ gradient that is maintained until a nerve impulse causes the gradient to be released (an action potential). Generally, diffusion and osmosis help molecules move to places where they belong - O_2 diffuses from the capillaries into the body cells that have less oxygen, nutrients move into cells that have less nutrients, and water moves down its gradient too – especially in plants, osmosis of water into roots from the soil is essential to maintaining a plant cell's turgid state).

<u>Models and Explanations:</u> This soap film is a model of the plasma (or cell) membrane. **A student who understands the fluid mosaic model for cell membranes can explain** that the soap film is a "water sandwich" – a layer of water positioned between two layers of soap molecules. The hydrophilic heads of the soap molecules point inward toward the water layer, and the hydrophobic tails of the soap molecules point toward the outside of the film, in contact with the air. The surface tension that causes bubble films (and bubbles) is due to the tendency of water, through hydrogen bonding, to minimize its surface area. When a finger wetted in bubble solution is inserted through the soap membrane the film remains in contact with a like solution and continues to minimize the surface area, and doesn't burst (the same with a water coated object). But, a dry object mechanically shears the film.

Further, a student who understands the concepts presented can discuss how plasma membranes are similar to soap films in several respects. They are both bilayered structures formed by molecules with hydrophobic and hydrophilic ends. The also both allow objects to move laterally within them – in the soap film, a wet finger can move around and not burst the film, and in a real plasma membrane, channel, or transport, proteins move laterally within the phospholipids. Third, plasma membranes and soap films are both flexible, non-rigid structures. Last, plasma membranes and soap films are both selectively permeable. Plasma membranes allow hydrophobic substances to pass through them much like soap films allow the bubble-wet finger to pass through. This is because hydrophobic substances are highly soluble in the lipid bipayer. Among polar (partially charged) molecules, only small ones, such as H_2O and CO_2 can easily pass through the spaces between phospholipids. Very large polar molecules (such as glucose) and fully-charged ions (such as Na+) require special transport proteins to help them cross the plasma membrane. These substances are like the dry finger inserted in the soap film – they cannot pass without special modifications. With appropriate modification, however, large or unlike substances can cross the plasma membrane (and the soap membrane). Plasma membranes use proteins embedded in the lipid bilayer to transport these substances across, like a channel. The hole created by the knotted string is much like a protein channel. One major difference between soap film membranes and real plasma membranes is that plasma membranes do not "pop" when confronted with an unlike substance.

Bibliography:

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Student Worksheet:

In this lab we will explore a model of a cell membrane. A **model** is a simplified representation of a complex biological structure or process. A model focuses on a few key features in order to help us understand a biological structure. Because a model is simpler than the biological structure it represents, a model does not demonstrate all the features of the actual biological structure. You will use the model to help **explain** how a cell membrane works.

Nutrients, respiratory gases, wastes and inorganic ions must all pass through a plasma membrane on their way into or out of every cell in your body cell. The cell, or plasma, membrane regulates what comes in and what goes out of the cell. Plasma membranes consist of a phospholipid bilayer, with each molecule having a hydrophobic tail and a hydrophilic head – so the two lipid strands form a "sandwich with the tails in the middle and the heads facing both inside and outside of the cell. This bilayer is studded with proteins that move laterally within the lipid membrane (like ice cubes floating in a a bucket of water), and is called a "fluid mosaic". Plasma membranes are **selectively permeable**: some substances can easily enter and exit the cell (or be transported in/ out of cells) and others cannot pass without assistance from the embedded proteins.

- Discuss three ways that plasma membranes are similar to the model of a plasma membrane made from a soap film.

- Discuss one way that plasma membranes are difference from the model of a plasma membrane made from a soap film.

- Based on your observations, what conditions allow objects to move through the soap membrane without popping it?

- What conditions cause the membrane to pop? Do you think the flexibility of the film influences its ability to resist popping?

- What types of substances do human beings need to take in / eliminate from their bodies? Do individual cells need to do similar things?

- Can you think of examples where water moves across a membrane?

- What roles do diffusion and osmosis play in the transport of materials across a plasma (cell) membrane?

<u>Draw a model to explain how a cell membrane works:</u>