Modeling Origins of Cells: the phospholipid membrane

When we see a cell membrane in a biology textbook we wonder how each molecule was drawn together to form such an impressive structure. In this experiment a small amount of egg yolk provides the cell membrane forming molecules so that with a shake we amazingly "self-assemble" real phospholipid membranes around oil and water droplets to demonstrate how easily polar forces construct such an important part of a living organism.

Materials: 125 ml flask with stopper, 50 ml graduated cylinder, Cooking oil, egg yolk, Eyedropper pipette, Water, iron filings, Test tube brush & soapy water

Procedures:
1. Add ~100 ml of water to flask. To that add 25 ml of oil.
2. Cover then shake for a second or two. Mixture should at first appear milky but quickly start separating.
3. While waiting for the oil to return to a clear layer on top. Use the eyedropper to extract ~2 drops of egg yolk.
4. By now the oil should have formed a clear layer on top. We first shook it to prove that it will do this. Notice that it is pure oil that can be seen through to the other side.
5. Then add one drop of the egg yolk into the flask. Adding too much can cause the oil to form such small droplets it becomes a colloid, like milk.
6. The drop of yolk will fall through the oil but float on the water so you can see it stuck in the middle.
7. Shake for a second or two like before.
8. Now watch what happens to the oil layer this time. It should soon look like a giant piece of tissue, like you're looking at cells under a microscope; but in this case, you see them with your own eyes!

· The less dense ones which contain only oil and have a phospholipid monolayer around them go to the top.
· The smaller phospholipid bilayer vesicles contain water inside and will be at the bottom of the layer, with some moving in the thermal convection currents of the water.
Discussion:
Phospholipid and cholesterol form membranes due to their having one end called a "head" which is attracted to the polar water, and on the other end are "tails" made of oil chains which are attracted to the nonpolar oil. Phospholipids and similar compounds will form a single "monolayer" membrane around grease, oil, and dirt, by their nonpolar "hydrophobic" tails sticking to the dirt while the water loving "hydrophilic" heads point outward to contact the water.

A phospholipid membrane which forms around a small droplet of water (instead of oil) is called a "Vesicle" which has a phospholipid "bilayer" where instead of a single membrane where all the tails stuck into an oil droplet there is a second inner membrane that has the phospholipid molecules pointing the other way so their heads contact the water droplet on the inside, with the tails of the inner membrane strongly attracted to the tails of the outer membrane which squeezes out anything that tries to come between them.

Vesicles are also very good at trapping such things as RNA and DNA which might end up included in your experiment, especially if you poked through the egg yolks nucleus when you took the sample.

Analysis Questions:
1. What are the bilayer membranes most like in cell biology? Monolayer membranes?

2. Did you notice any of the droplets growing or dividing? What might this be related to in terms of cell organization?

3. What aspects of a complete living single cell are missing in this demo?

4. Predict what might happen if you add iron particles. If time test your prediction by adding some iron filing dust to the mixture. Record your observations.
NOTES on Cell Membrane structure and function

1. Cell Structure
   a. Cells are a variety of sizes
      i. Smallest cells – mycoplasma - 0.2 micrometers in diameter
      ii. Largest cell – ostrich egg – 45 centimeters across
      iii. Giant amoeba – Chaos chaos – 1000 micrometers
      iv. Most are between 5 and 50 micrometers.
      v. Limited growth due to limits on the flow of information between or materials in and out of the cell.
   b. Three basic structures common to cells and related organisms
      i. Cell membrane – or outer boundary of the cell
      ii. Cytoplasm – material inside the membrane surrounding the nucleus
      iii. Ribosome – site of protein synthesis
   c. Cell Membrane
      i. Regulates what enters and leaves the cell
      ii. Aids in the protection and support of the cell
      iii. Fluid-Mosaic Model of the cell membrane
         1. Phospholipid bilayer
         2. Embedded Proteins
            a. stuck to surface
            b. free moving between layers
            c. form channels to allow molecules in and out of cell
            d. act as molecule pumps to push materials from one side of the membrane to the other.
      3. Carbohydrates
         a. Stuck to lipids and proteins
         b. Act as chemical identifiers for the cells to recognize and interact with each other.

2. Movement of Materials Through the Cell Membrane
   a. All cells exist in a liquid environment
      i. Many organisms surround their cells with blood because the concentrations of the blood and the cells are roughly the same.
      ii. Plants and bacteria use cell walls to maintain a constant size even under high osmotic pressure. Unfortunately this makes the cell wall vulnerable to injury
      iii. Some unicellular organisms have a contractile vacuole that rhythmically pumps water out of the cell.
iv. Concentration in cells
1. In two solutions, the less concentrated (more water) solution – hypotonic
2. In two solutions, the more concentrated (less water) solution – hypertonic
3. If two solutions are the same concentration – isotonic

b. Methods of material transport in and out of cell
i. Diffusion
1. Passive Transport – does not require energy
2. Process by which molecules move from high concentration to low concentration
3. Substances continue to move across the membrane until equilibrium is reached – equal concentrations
4. Molecules may continue to move in and out but there is no significant change in concentration once equilibrium is reached
5. Permeability
   a. If a substance can cross – the membrane is permeable to that substance
   b. If a substance cannot cross – the membrane is impermeable
   c. Membranes that are permeable to some substances and not to others are called selectively-permeable

ii. Facilitated Diffusion
1. Passive Transport – does not require energy
2. Process that transports molecules across the membrane with a carrier protein.
   a. Red blood cells have a glucose transporter protein to help with the diffusion of glucose across the membrane
   b. Used with molecules that do not dissolve in or easily pass through the lipid bilayer
3. Fast, specific, and does not require energy
4. Can only occur though if there is a concentration difference
5. Osmosis
   a. Movement of water through the membrane
   b. Aquaporin – protein channel; helps transport water molecules rapidly through membrane
c. Water moves from areas of high water concentration to low water concentration.
d. Force exerted by osmosis – osmotic pressure
   i. Moves water from hypotonic solutions to hypertonic solutions
   ii. Isotonic solutions have no osmotic pressure
   iii. Problems caused by osmotic pressure
       1. Due to high concentrations in cells of salts, sugars, proteins, etc. cells must guard against the free movement of fresh water into the cell.
       2. Too much fresh water causes cells to swell and burst

iii. Active transport
   1. Energy requiring process that enables material to move across a membrane against a concentration difference.
   2. Two types of active transport
      a. Individual molecules are carried through membrane-associated pumps – molecular transport
         i. Special transport macromolecules move ions such as calcium, potassium, and sodium
         ii. All cells transport at least a few molecules in this way
         iii. Allows cells to force stronger or weaker concentrations as needed.
      b. Large amounts of materials are transported through movements of the cell membrane – bulk transport
         i. Endocytosis – taking materials in through pockets of cell membrane.
            1. a large particle – phagocytosis
            2. liquids – pinocytosis
         ii. includes large molecules, food, liquids, whole cells
         iii. Exocytosis – sending material out of the cell
            1. Such as water – contractile vacuole
            2. Membrane of vacuole fuses with the cell membrane and forces the contents out.
Name ______________________________________ Period _____ Date _______________________

CELL MEMBRANE STRUCTURE AND FUNCTION – note taking worksheet

Cell Structure

How do cells vary in size?
The smallest cells are ___________________ which are 0.2 micrometers in diameter.

The largest cells are ____________________ which can be 45 centimeters across.

A Giant amoeba (Chaos chaos) is __________ micrometers, but most cells are between _____ and ______ micrometers.

Cells are limited in ________________ due to because growing too large puts stress on the movement of materials in and out of the cell.

Three basic structures common to cells and related organisms

_________________________ – or outer boundary of the cell

_________________________ – material inside the membrane surrounding the nucleus

_________________________ – site of protein synthesis

Cell Membrane

Regulates what _____________ and _______________ the cell

Aids in the ________________ and support of the cell

Fluid-Mosaic Model of the cell membrane

Phospholipid bilayer

Proteins

stuck to _________________

free _________________ between layers

form _________________ to allow molecules in and out of cell

act as molecule _________________ to push materials from one side of the membrane to the other.

Carbohydrates

Stuck to lipids and proteins

Act as chemical _________________ for the cells to recognize and interact with each other.
Movement of Materials through the Cell Membrane

All cells exist in a _______________ environment

Why do cells need this environment?

Concentration in cells

In two solutions, the less concentrated (more water) solution – _______________

In two solutions, the more concentrated (less water) solution – _______________

*Draw a diagram to showing a cell that is hypotonic (more water, less solute) inside and hypertonic (less water, more solute) outside. Label the hypotonic and hypertonic side.*

If two solutions are the same concentration – _______________

*Draw a diagram to showing a cell that is isotonic with its environment.*

Two Types of Transport: Passive and Active Transport

**Passive Transport** - ______________________________

**Diffusion**

This process by which molecules move from _________ concentration to _______ concentration

Substances continue to move across the membrane until equilibrium is reached – equal concentrations

Molecules may continue to move in and out but there is no significant change in concentration once equilibrium is reached
Permeability
If a substance can cross – the membrane is __________________ to that substance
If a substance cannot cross – the membrane is __________________
Membranes that are permeable to some substances and not to others are called ____________________________

Facilitated Diffusion
This process transports molecules across the membrane with a __________________
_________________.
Used with molecules that do not ________________ in or easily pass through the lipid bilayer
Fast, specific, and does not require energy
Can only occur though if there is a concentration difference
Example of Facilitated Diffusion

Osmosis
Movement of ______________ through the membrane
Needs an __________________ – protein channel; helps transport water molecules rapidly through membrane
Water moves from areas of ________ water concentration to _________ water concentration.
Force exerted by osmosis – ______________ __________________
Moves water from ______________ solutions to hypertonic solutions

______________ solutions have no osmotic pressure

Osmotic pressure is good for moving water across the cell membrane when needed, but what problems can be caused by osmotic pressure?
Active transport - ________________ requiring process that enables material to move across a membrane against a concentration difference.

Two types of Active transport

Individual molecules are carried through membrane-associated pumps – ________________ transport

- Special transport macromolecules move ions such as calcium, potassium, and sodium
- All cells transport at least a few molecules in this way
- This allows cells to force stronger or weaker concentrations as needed.

Large amounts of materials transported through movements of the cell membrane – _______ transport

Endocytosis – taking materials in through pockets of cell membrane.

- Bringing in a large particle is called __________________________
- Bringing in liquids is called __________________________

Endocytosis can include large molecules, food, liquids, or even whole cells

Exocytosis – sending material out of the cell

- Some cells have to push water out of the cell continually. They use a ________________

- ________________

- Proteins synthesized inside the cell are excreted when the membrane of a vesicle fuses with the cell membrane and forces the contents out.

Summarize the cell membranes role and structure in 20 words (no more, no less)

_____________________________ ________________ ________________ _______________ ______________
_____________________________ ________________ ________________ _______________ ______________
_____________________________ ________________ ________________ _______________ ______________
_____________________________ ________________ ________________ _______________ ______________
Build Your Own Fluid Mosaic Model of the Cell Membrane

Directions: Using the materials in class, your notes, and the research you conducted, build a model of a cross-section of a cell’s plasma membrane. Be prepared to explain the model to your instructor for credit!

Items that must be included in your model:

- Phospholipids (properly built) in a bilayer
- Peripheral protein
- Cholesterol
- Aquaporin
- Cytoskeleton filaments
- Glycoprotein
- Vesicle containing a protein destined for secretion/excretion from the cell
- Water molecules
- Integral protein
- Trans-membrane/channel protein
- Sodium ions
- Extracellular protein signal
- Receptor protein

Items that also must be located or demonstrated/explained with your model:

- Locate hydrophilic region of membrane
- Locate hydrophobic region of membrane
- Locate cytoplasm
- Locate extracellular fluid
- Components of phospholipids
- Secretion/excretion of a protein contained in a vesicle
- Movement of water through membrane
- Receptor protein receiving an extracellular protein signal
- Movement of sodium ions through membrane

1. Instructor approval of model and its explanation: ___________
2. Once your instructor has approved your model, sketch it on the back of this sheet. Be sure to LABEL all the components!
DIAGRAM OF FLUID MOSAIC MODEL OF CELL MEMBRANE
Diagram the model you created.
LABEL ALL OF THE COMPONENT PARTS
Post-lab questions:

1. Draw a phospholipid. Label its polar and nonpolar regions.

2. Investigate to find out if other than the plasma membrane, there are any other eukaryotic organelles composed of a similar bilayer?

3. Explain why the cell’s plasma membrane is called selectively (or semi) permeable.

4. Explain the difference between polar and nonpolar molecule interactions with the cell membrane?

5. How does the plasma membrane’s structure allow it to act as a protective barrier for the cell?

6. What is the function of trans-membrane/channel proteins?

7. Why are components of the cytoskeleton attached to the membrane?
8. Based on your model and research, explain how water moves through the membrane.

9. Based on your model and research, describe how potassium ions are transported through the membrane.

10. Describe the structure of a vesicle.

11. What is the purpose of the glycoproteins on the outside of the cell?

12. Explain how receptor proteins control specific cell responses.

13. How does the plasma membrane’s structure allow it to act as a regulatory structure for the cell?
### Build Your Own Fluid Mosaic Model of the Cell Membrane – Assignment Rubric

To complete the assignment and receive full credit for the activity follow the rubric guidelines

<table>
<thead>
<tr>
<th>Section</th>
<th>Full Credit</th>
<th>Partial Credit</th>
<th>No Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Student brings to class complete list of vocabulary and select images to help construct the Playdoh model of the cell membrane</td>
<td>Students vocabulary list does no identify all the key components or is missing some structures in the images selected to help construct the Playdoh model of the cell membrane</td>
<td>Student did not complete the vocabulary identification or bring select images to help construct the Playdoh model of the cell membrane</td>
</tr>
<tr>
<td>Model Building</td>
<td>Student fully collaborates with teammates to help construct the Playdoh model of the cell membrane The model contains all identified structures.</td>
<td>Student participation is limited to help construct the Playdoh model of the cell membrane The model contains some to most identified structures.</td>
<td>Did not participate or contribute to help construct the Playdoh model of the cell membrane</td>
</tr>
<tr>
<td>Modeling Processes</td>
<td>Student is able to demonstrate all processes with the model</td>
<td>student is able to demonstrate some processes with the model</td>
<td>Student cannot demonstrate processes with the model</td>
</tr>
<tr>
<td>Diagram and Analysis Questions</td>
<td>Student completely and accurately represents model in diagram and answer with detail and support the analysis questions.</td>
<td>Student diagrams the cell membrane with some missing or mislabeled components and answers the analysis questions but does not provide essential details that demonstrate full comprehension.</td>
<td>Student diagram is limited in structures or labeled parts or students did not complete the questions in the analysis section completely or correctly.</td>
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</tbody>
</table>
Build Your Own Fluid Mosaic Model of the Cell Membrane

Assessment Form

Group Members: ___________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

Assessment Checklist:

Items that must be included in your model:

☐ Phospholipids (properly built) in a bilayer
☐ Peripheral protein
☐ Cholesterol
☐ Aquaporin
☐ Cytoskeleton filaments
☐ Glycoprotein
☐ Vesicle containing a protein destined for secretion/excretion from the cell
☐ Water molecules
☐ Integral protein
☐ Trans-membrane/channel protein
☐ Sodium ions
☐ Extracellular protein signal
☐ Receptor protein

Items that also must be located or demonstrated/explained with your model:

☐ Locate hydrophilic region of membrane
☐ Locate hydrophobic region of membrane
☐ Locate cytoplasm
☐ Locate extracellular fluid
☐ Describe the components of phospholipids
☐ Explain the secretion/excretion of a protein contained in a vesicle
☐ Describe the movement of water through the membrane
☐ Demonstrate a receptor protein receiving an extracellular protein signal
☐ Demonstrate the movement of sodium ions through the membrane

Final Score: ____________
Two main categories of membrane proteins - integral and peripheral

Peripheral proteins - bound to the surface of the membrane

Integral proteins – in the membrane - i.e. aquaporin – water channel protein

Cholesterol in the Bilayer

Channel and Signal Functions in the membrane