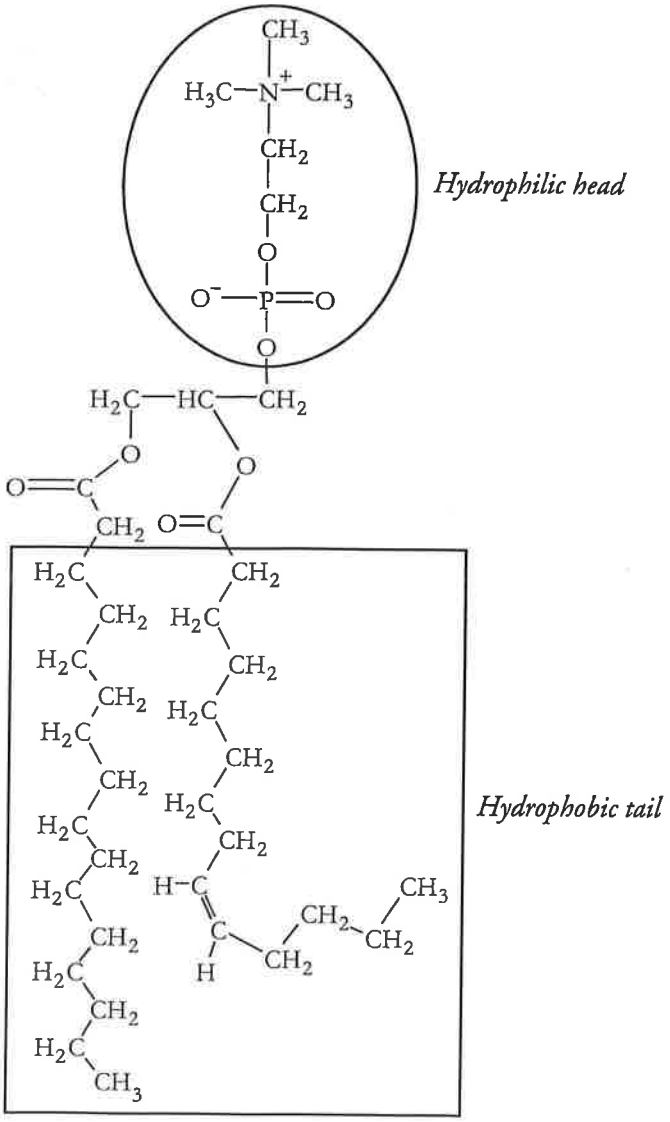
Membrane Structure

What molecules make up a membrane?

Why?

Imagine your bedroom without closets, drawers, shelves, bags or boxes—just a room with a bed. Where would your stuff be? Would you be able to find the things you needed? How efficiently could you get ready for school in the morning? Would all of your school items be together when you sat down to study? The compartments you use in your room—the closet, drawers, etc.—help you organize items by category so that all the items you need to get dressed are in one place. All the items you need for studying are in another place. This **compartmentalization** improves efficiency. Cells also need organization to improve efficiency. The compartmentalization of cells is achieved by dividing up areas in the cell with membranes. A plasma membrane compartmentalizes internal structures while the cell membrane acts as a boundary between the cell and the external environment.

Model 1 – Phospholipids



1. Refer to Model 1. Identify at least two organic functional groups in a phospholipid molecule.

   The model shows ester functional groups (—C(=O)—O—R), an amine [$N^+(CH_3)_3$], a phosphate group, an alkene (—CH=CH—), and alkane side chains.

2. Consider the term phospholipid.

   a. What portion of the molecule in Model 1 is responsible for the "phospho-" part of the name?

   The phosphate group (PO_4) at the top of the molecule.

   b. What portion of the molecule in Model 1 is responsible for the "-lipid" part of the name?

   The long hydrocarbon chains attached with ester groups.

3. Part of a phospholipid is polar.

   a. Circle the portion of the molecule in Model 1 that is polar.

   See Model 1.

   b. Would this portion of the phospholipid mix well with water? Explain your reasoning.

   Water is polar and tends to dissolve polar molecules. This portion of the molecule would mix with water.

4. Part of a phospholipid is nonpolar.

   a. Draw a square around the portion of the molecule in Model 1 that is nonpolar.

   See Model 1.

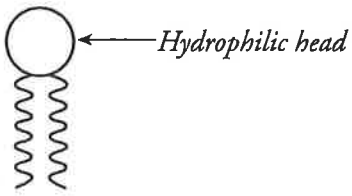
   b. Would this portion of the phospholipid mix well with water? Explain your reasoning.

   Water is polar and therefore does not mix well with nonpolar molecules.

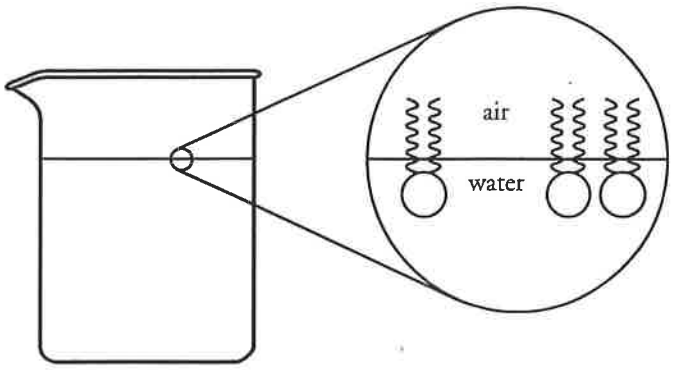
5. Label the regions of the molecule in Model 1 with the phrases "hydrophilic head" and "hydrophobic tail."

   See Model 1.

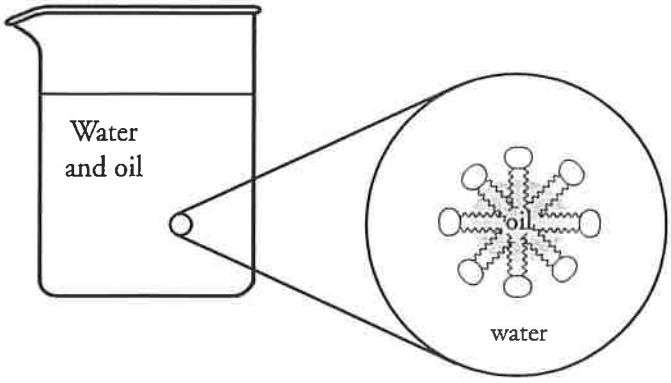
6. Scientists often use a cartoon representation like the one shown below to represent a phospholipid. Which portion of the cartoon represents the hydrophilic head of the phospholipid?



7. When phospholipids are placed on the surface of water they form a thin layer. Consider carefully which portion of the phospholipid will be in the water and which will be in the air in order to obtain the most stable (lowest potential energy—maximum attractions) system. Draw a cartoon-like representation below to show the proper orientation of three phospholipid molecules on the surface of water.



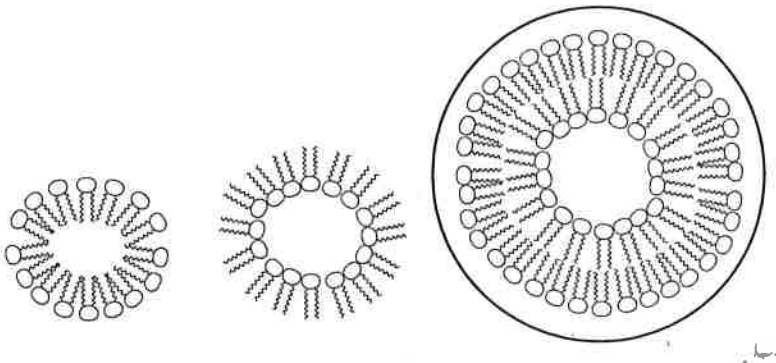
8. When a small amount of oil is added to a beaker of water containing phospholipids, the phospholipids will surround the oil droplets forming **micelles**. Use several cartoon representations of phospholipid molecules to show the arrangement or orientation of phospholipids in a micelle.



9. Recalling that a beaker of water is three-dimensional, what is the three-dimensional shape of the micelle?

   Spherical (a circle in three dimensions).

10. Phospholipids assemble in layers to make membranes for cells and organelles. Circle the drawing below that represents the most stable (lowest potential energy) assembly of phospholipids where water is both inside and outside of the membrane. (This might be the membrane on a vacuole for instance.) Explain your reasoning.



Since water is both inside and outside the membrane, the polar head of the phospholipid must face both inside and outside. Since this is not possible with one molecular layer, two layers form.

STOP

11. How do phospholipid molecules lead to compartmentalization of a cell?

Answers will vary. Since the phospholipids form layers and micelles, they form small areas or compartments where the inside and outside do not touch. The phospholipid molecules become boundaries between two fluids.

Read This!

When phospholipids are added to an aqueous environment (consisting mostly of water) the phospholipid molecules will spontaneously assemble into a **phospholipid bilayer** where the layers are held together by weak attractive forces between molecules. These structures are often seen in nature as cell and organelle membranes.

12. Consider animal cells, which are only bound by a cell membrane and plant cells which are bound by both a cell membrane and a cell wall. Are cell membranes flexible (fluid)? Provide specific examples to support your answer.

Cell membranes are flexible. An amoeba, for example, appears to change its shape as it consumes food or moves about responding to its environment. Plants, which need a rigid cellular structure for support, require a cell wall because the membrane is not strong enough to support the plant.

13. Explain why a phospholipid bilayer is flexible in terms of the strength of the forces that hold it together.

Phospholipids are held together by weak forces between the molecules making up the bilayer—the molecules can slide past each other and change position in the bilayer. This allows the membrane to be flexible.

14. Refer to Model 1.

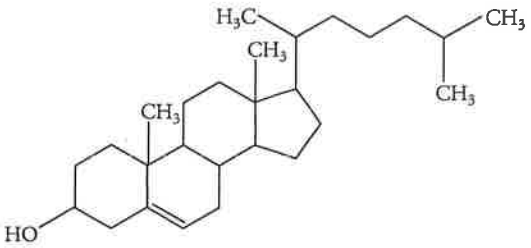
a. What happens to the shape of the hydrophobic tail in a phospholipid when a double bond is present in the carbon chain?

The carbon chain appears bent when a double bond is present.

b. Explain why the flexibility (fluidity) of a membrane increases when more of the phospholipids in the layers contain double bonds.

When the tail of the phospholipid is bent, the molecules cannot assemble as tightly. This will increase flexibility of the membrane.

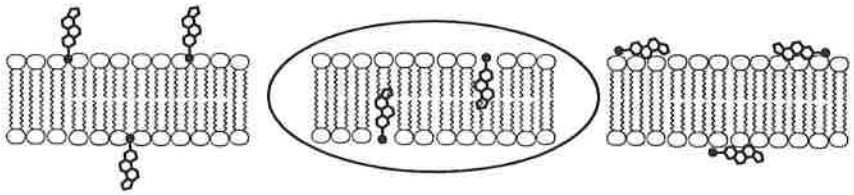
15. The diagram below shows the chemical structure of cholesterol, which is a key component of membrane structure.



a. Is the cholesterol molecule mostly polar or mostly nonpolar? Explain.

Cholesterol is mostly nonpolar—it consists primarily of C—C and C—H bonds, with only one polar O—H bond.

b. Circle the drawing below which illustrates the most likely placement of cholesterol in a phospholipid bilayer.

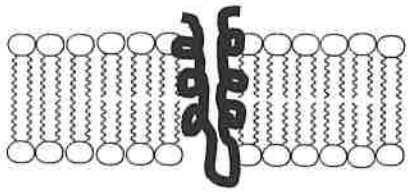


c. The cholesterol forms weak attractive forces with multiple phospholipids in the bilayer. Would this increase or decrease flexibility of the membrane? Explain your reasoning.

There would be a decrease in flexibility because more bonds are formed. The phospholipids would not be able to slide past one another when the membrane was bent.

Extension Questions

16. **Embedded proteins** are often found spanning the membrane of a cell or organelle. These proteins serve as channels for specific molecules to travel through the membrane, either into or out of the cell.



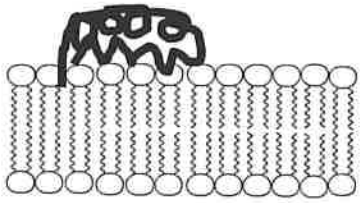
a. What sections of the embedded protein chain are most likely to contain amino acids with hydrophobic R-groups? Explain your reasoning.

The sections of the protein that are embedded in the membrane are most likely to have hydrophobic R-groups. These R-groups would undergo hydrophobic interactions with the hydrophobic tails of the phospholipids and hold the protein in place.

b. What sections of the embedded protein chain are most likely to contain amino acids with hydrophilic R-groups? Explain your reasoning.

The sections of the protein that are on the surface of the membrane (the entrance and exit) are most likely to have hydrophilic R-groups. These R-groups would be in contact with the cytoplasm and extracellular fluid, which are mostly water.

17. Some membranes have **surface proteins** on them. These proteins often serve a signaling function between cells. Propose a mechanism by which these surface proteins are able to attach to the membrane.



The surface protein is most likely attached to the membrane by interactions between the hydrophilic (polar) heads of the phospholipids and hydrophilic R-groups in the protein. These interactions could be hydrogen bonds or ionic interactions.

Teacher Resources – Membrane Structure

Learning Objectives

1. Describe phospholipids as both hydrophobic and hydrophilic.
2. Explain how these properties affect how phospholipid molecules arrange when in contact with water.
3. Describe the arrangement of the phospholipid bilayer of a membrane.

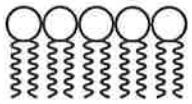
Prerequisites

1. Students should be able to identify polar bonds or polar groups in a molecule. See *Biochemistry Basics* in POGIL Activities for AP* Biology.
2. Students should have knowledge of hydrophobic and hydrophilic substances.
3. Students should understand the idea of "like dissolves like"—that polar substances will mix well with each other and nonpolar substances will mix well with each other, but polar substances do not mix well with nonpolar substances.
4. Students should have knowledge of the following functional groups—esters, carboxyl, amine, phosphate, and alkene. See the *Biological Molecules* activity in POGIL Activities for High School Biology.

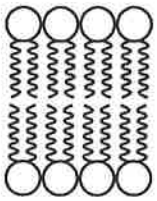
Assessment Questions

1. Which of the following diagrams shows the correct arrangement in a phospholipid bilayer?

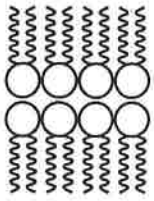
a.



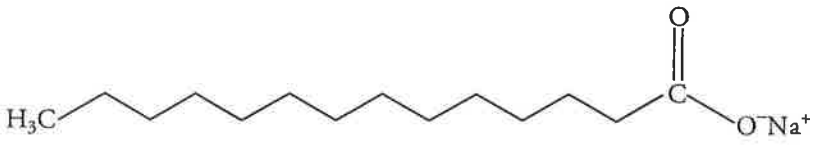
b.



c.



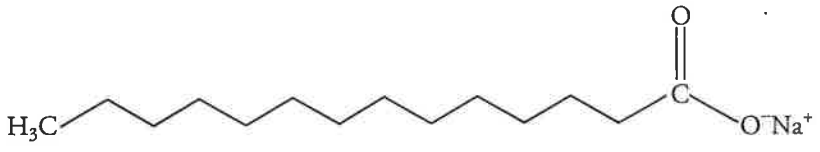
2. Given that a phospholipid is polar at one end and nonpolar at the other, how can phospholipids act as a barrier between two polar solutions (like water in a vacuole and the cytoplasm of a cell)?
3. The chemical structure of a soap molecule is shown below.



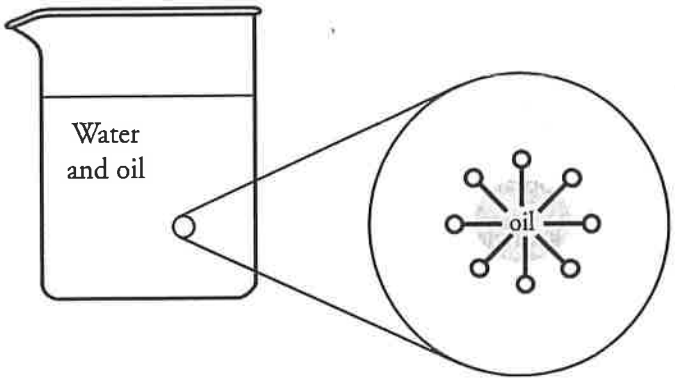
a. Identify the hydrophilic and hydrophobic regions on the soap molecule.

b. Draw a cartoon representation of a soap molecule forming a micelle around a droplet of oil in water.

Assessment Target Responses

1. *b.*
2. *In water, phospholipids will orient themselves so that the hydrophobic tails are away from the water while the hydrophilic heads interact with the water. One way to accomplish this is to have a bilayer with the tails in the middle and the heads oriented on the two outer surfaces.*
3. 

Hydrophobic *Hydrophilic*



Teacher Tips

- After completing this activity, a teacher might introduce the idea that soaps and detergents are very similar to phospholipids and therefore can get into the phospholipid bilayers of most membranes and disrupt their function.
- A molecule that remains at the surface of water is called a surfactant. This is addressed in Question 7, although that specific vocabulary is not used. The surfactant will interact with the water molecules of the surface. This may be a good place to discuss environmental issues like surfactants getting into water supplies, often causing surface tension of water to decrease, which causes problems for organisms like bugs that walk on the surface of water.
- Embedded proteins are sometimes called integral proteins, transmembrane proteins or spanning proteins. Surface proteins are sometimes called peripheral proteins or glycoproteins.
- The Flinn Scientific *Plasma Membrane Model,* Catalog No. FB1768, demonstrates the fluid mosaic membrane model with simulated phospholipids and proteins to show the lipid bilayer.