Student Handout 1

Big Idea

In the biological sciences, a dehydration synthesis (condensation reaction) is typically defined as a chemical reaction that involves the loss of water from the reacting molecules. This reaction is used in the formation of carbohydrates, proteins, triglycerides and phospholipids.

Introduction to Lipids

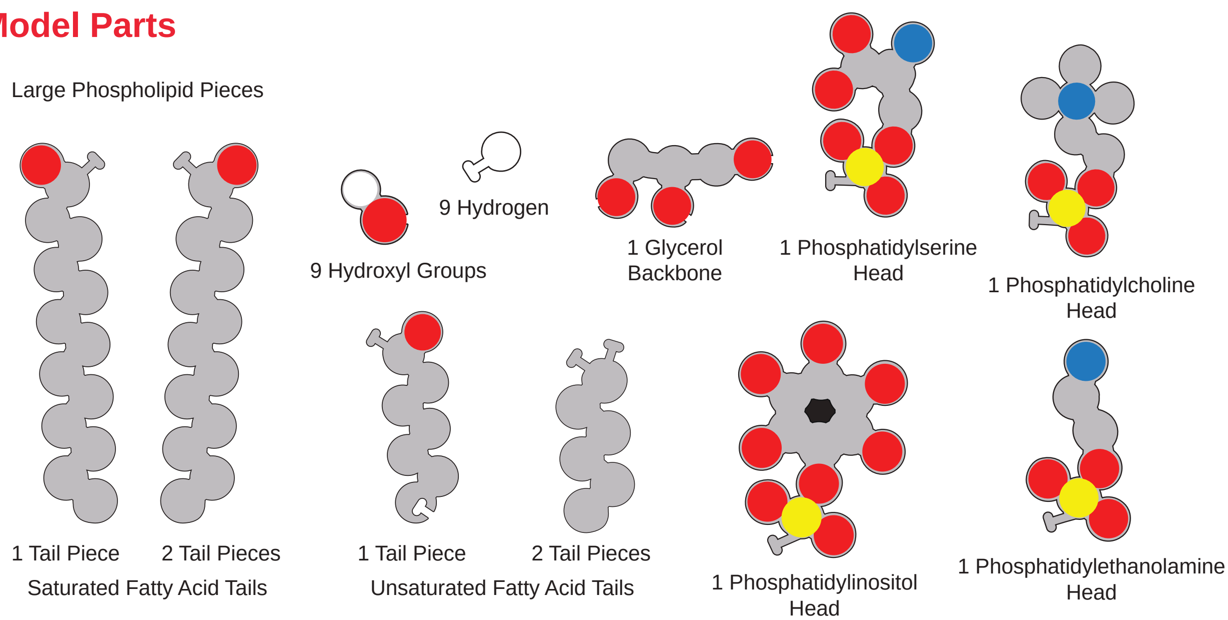
Biomolecules are molecules unique to living systems and include **carbohydrates**, **proteins**, **nucleic acids** and **lipids**. Lipids are a diverse group of organic compounds primarily composed of carbon, hydrogen and oxygen. Fatty acids, triglycerides, phospholipids, fat-soluble vitamins and steroids are a few examples of molecules classified as **lipids**.

The main biological functions of the many varied types of lipids include:

- energy storage
- protection
- insulation
- regulation of physiological processes

Some lipids serve as the structural components of cell membranes.

Model Parts



Color Scheme

Oxygen (red)	Nitrogen (blue)	Phosphorus (yellow)	Hydrogen (white)	Carbon (grey)

Note: This kit follows CPK coloring except for phosphorous, which we show in yellow.

Phospholipid Activity 1 Continued

Hydrophobic and Hydrophilic Properties

Understanding the concepts of **hydrophobic** and **hydrophilic** are key to understanding membrane structure. You can divide the words into their two parts to find clues to their meaning. “Hydro” means water and “phobic” means fear of. Hydrophobic regions of molecules don’t interact with water molecules.

1. Separate the word hydrophilic into two parts and record what each of these parts means.

   Hydro means _______________and *philic* means_______________.

2. What characteristics would a hydrophilic molecule exhibit?

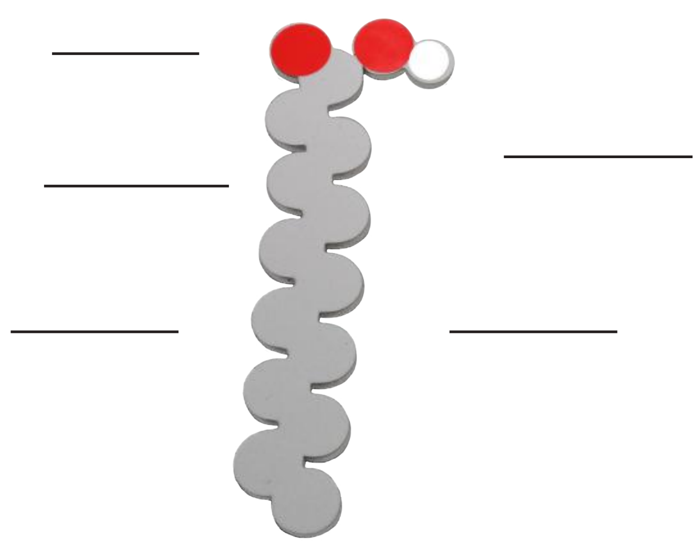
   ____

You may also see hydrophobic molecules called non-polar and hydrophilic molecules called polar.

What’s a Lipid?

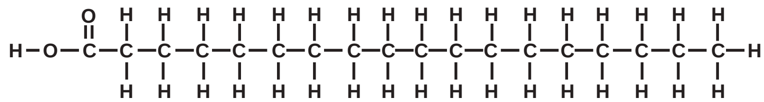
Fatty acids are **linear chains of carbon and hydrogen atoms** with an **organic acid group** (-COOH) at one end. Examine the model of a fatty acid pictured in the box below.

1. Review the image of the phospholipid tail, one of the foam model pieces in the kit.
   a. Label the carbon, oxygen and hydrogen atoms, and note the hydrophobic and hydrophilic regions of the molecule.
   b. Draw the molecular formula for this fatty acid.

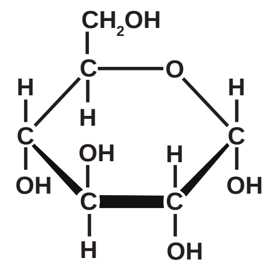


Phospholipid Activity 1 Continued

2. Look at the chemical structures of the common fatty acid stearic acid and the common carbohydrate glucose. Compare the proportion of carbon atoms to oxygen atoms in the table below.



Stearic Acid



Glucose

Substance	Formula	# of C atoms	# of O atoms	Ratio of C:O	Ratio of C:H
Stearic acid					
Glucose					

3a. What do you notice about the amount of oxygen in a fatty acid compared to oxygen in a carbohydrate?

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3b. What do you observe about the ratio of carbon to hydrogen in a fatty acid compared to a carbohydrate?

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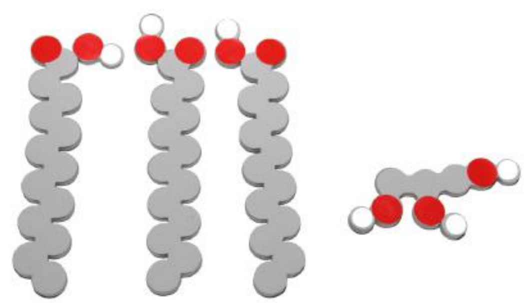
Triglycerides are neutral fats. Some triglycerides are considered **fats** and others **oils**. When a triglyceride is a **solid** at room temperature it is a **fat**. When a triglyceride is a **liquid** at room temperature it is an **oil**. The two building blocks that compose triglycerides are fatty acids and glycerol.

4. Label the glycerol and fatty acids in the diagram below.



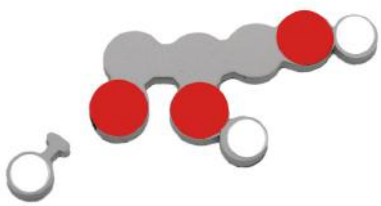
Phospholipid Activity 1 Continued

Forming Triglycerides

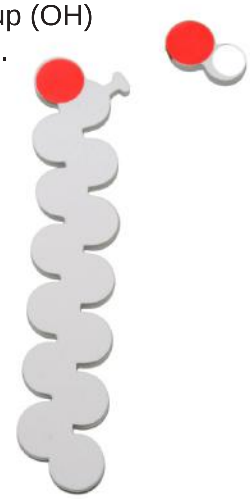
In this activity you will model a dehydration synthesis reaction in the formation of a triglyceride and determine the resulting products.

1. Begin with glycerol and three of the straight-chain fatty acids as the reactants in this simulation. A fatty acid is said to be saturated if the carbons comprising the tail are all singly bonded to each other.

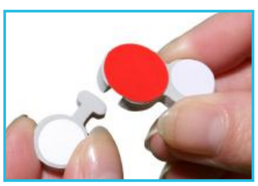
2. Remove one of the hydrogen (H) atoms from the glycerol.



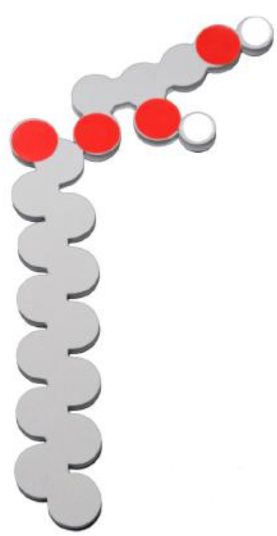
3. Remove the hydroxyl group (OH) from one of the fatty acids.



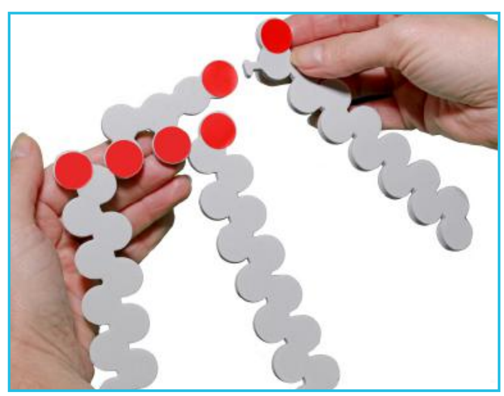
4. Combine the H and the OH.



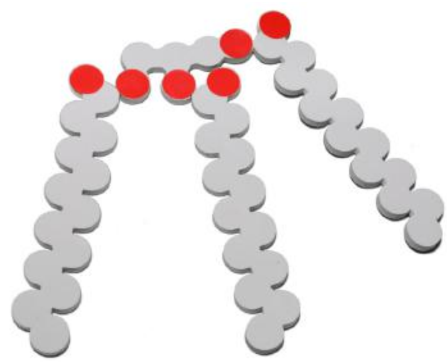
5. Join the fatty acid to the glycerol.



6. Repeat this process with the two remaining fatty acids.



Phospholipid Activity 1 Continued



a. How many water molecules were formed in this reaction? ________________

b. What are the final products of this dehydration synthesis?

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c. Predict whether you think this resulting triglyceride would most likely be a fat or an oil? Explain your reasoning.

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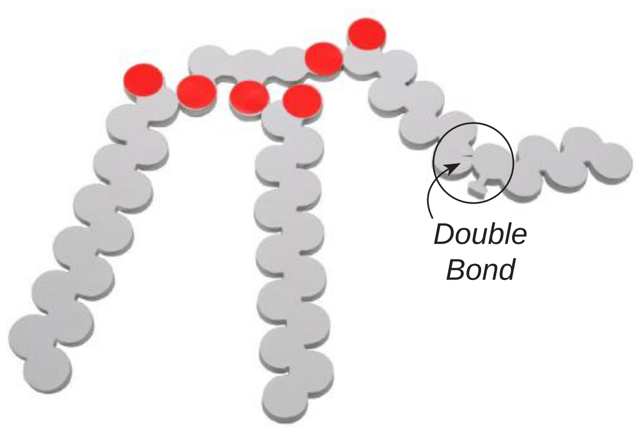
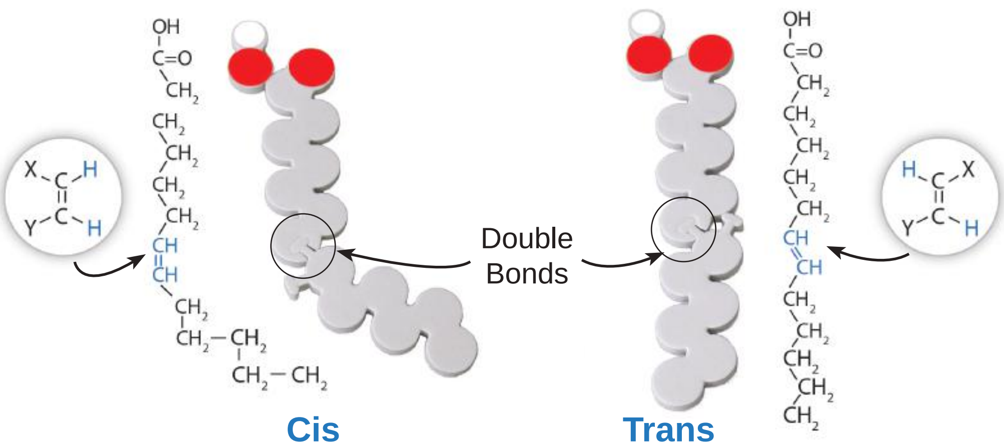
7. Substitute the third fatty acid tail with the two-part fatty acid tail. The post and hole connection in the two-part tail symbolizes a **double bond** between the carbons. When one or more double bonds are present between the carbons in the tail of the fatty acid, the molecule is **unsaturated**.



Phospholipid Activity 1 Continued

The double bond in an unsaturated fatty acid may form one of two possible configurations: *trans* or *cis*. You may model the trans configuration by attaching the second piece of the tail to the first to produce a straighter chain. The *cis* configuration may be modeled by producing a kinked configuration. Most naturally-occurring unsaturated fats are in the cis configuration.

If the hydrogens associated with the double bonded carbons are on the same side, the fatty acid is called *cis*. If the hydrogens associated with the double bonded carbons are on opposite sides, the fatty acid is called *trans*. (See illustrations below.)



d. Which configuration produces the bigger **kink** in the structure of the hydrocarbon chain of the triglyceride?

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e. Explain how the cis or trans configurations might contribute to the triglyceride being an oil or a fat?

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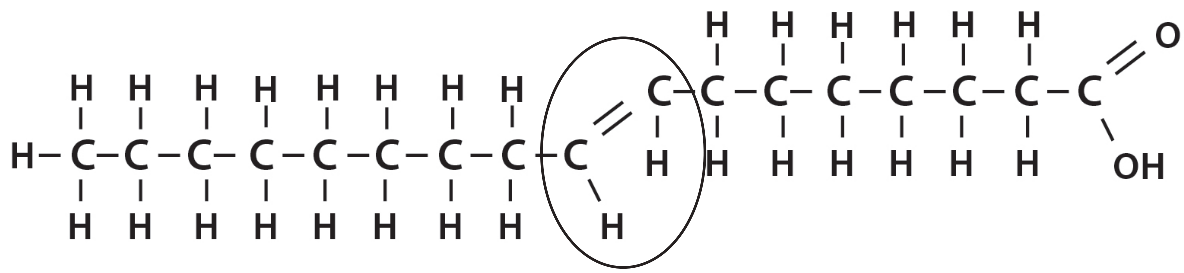
Phospholipid Activity 1 Continued



f. Is the fatty acid in the diagram above in the cis or trans configuration? Explain.

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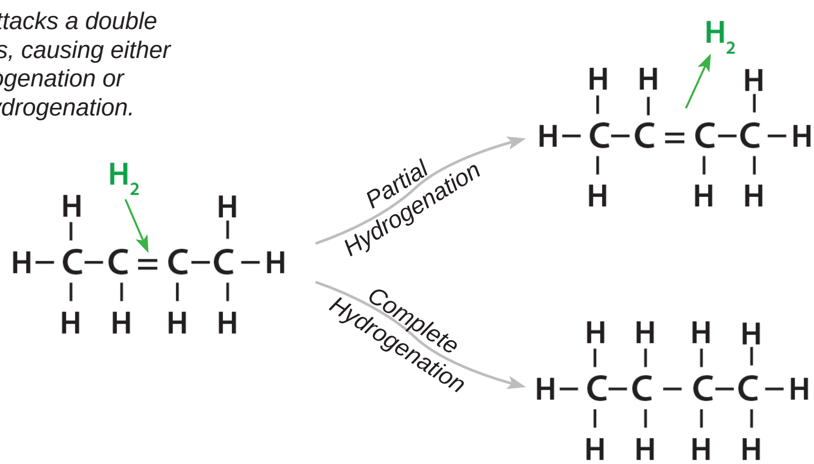
Hydrogenation occurs when hydrogen atoms are added to an unsaturatured fatty acid tail, causing double bonds between atoms to become single bonds.

Full hydrogenation occurs when all double bonds convert to single bonds resulting in a saturated fatty acid.

Partial hydrogenation occurs when some of the double bonds are replaced with single ones. Trans fat may be created in partial hydrogenation.

Hydrogen attacks a double bond of a cis, causing either partial hydrogenation or complete hydrogenation.



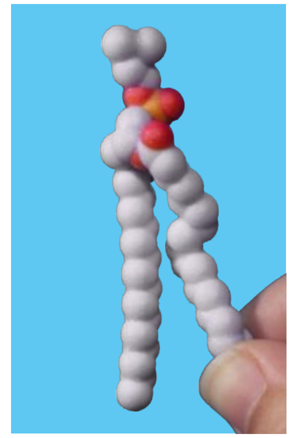
A hydrogen atom moves to the other side of the double bond, creating a trans isomer.

A hydrogen atom adds to each side of the double bond, saturating the hydrocarbon chain.

Phospholipid Activity 1 Continued

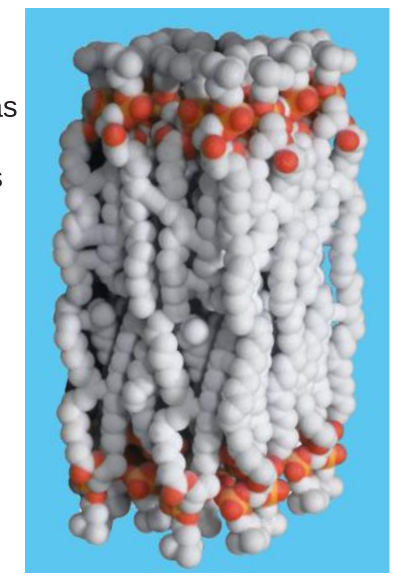
Introduction to Plasma Membranes

The **plasma membrane** is the structural boundary that separates the cell from its surroundings and controls what substances move into and out of the cell. As only some substances are allowed to cross the membrane, the plasma membrane demonstrates the property of **selective permeability**. The plasma membrane is also called a cell membrane.



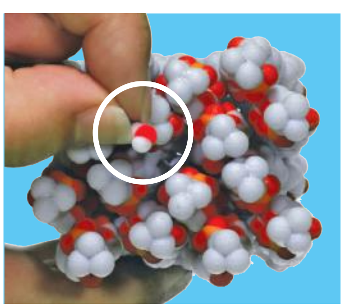
Plasma membranes primarily consist of phospholipids. Note the hydrophobic and hydrophilic regions of the lipid.

In particular, the plasma membrane of mammalian red blood cells (erythrocytes) has been the focus of cell membrane study because these cells do not contain nuclei or internal membranes. They represent a source from which a pure plasma membrane may be easily isolated for analysis. In 1925, Dutch scientist Evert Gorter and his research assistant F. Grendel extracted lipids from the membranes of a known number of red blood cells which corresponded to a known surface area of plasma membrane. The surface area occupied by a monolayer of the extracted lipid and the air/water interface was then determined. The results of their experiment showed that the surface area of the lipid monolayer was twice that occupied by the erythrocyte plasma membrane, leading to the conclusion that the plasma membrane consists of two layers called the **lipid bilayers**.



In the plasma membrane the hydrophobic tails come together while the hydrophilic heads of each layer orient themselves toward the watery environments inside and outside of the cell.

The most abundant lipids in most membranes are **phospholipids**. The ability of phospholipids to spontaneously form membranes is inherent to their **amphipathic** (containing both hydrophilic and hydrophobic regions) nature. The "head" of a phospholipid is composed of the negatively- charged phosphate group and may contain other polar groups. The tail of a phospholipid usually consists of long fatty acid hydrocarbon chains.



*Water molecules (shown in the circle in the photo left) can pass in and out of a cell through a plasma membrane, but not easily. **Aquaporin**, a protein embedded in the membrane (shown in the photo right), facilitates passage of water molecules in and out of the cell.*

These models are from 3D Molecular Designs' Molecules of Life Collection©. They can be borrowed from the MSOE Lending Library **cbm.msoe.edu/teachRes/library/ml.html** *or purchased from 3D Molecular Designs* **3dmoleculardesigns.com/Education-Products/Molecules-of-Life-Collection.htm**.

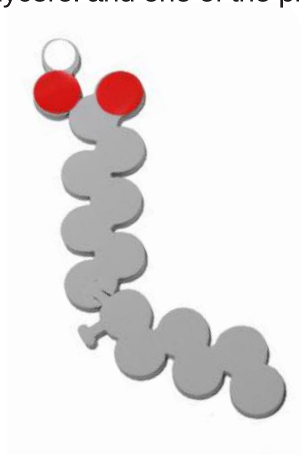
Phospholipid Activity 1 Continued

Focus on Phospholipids

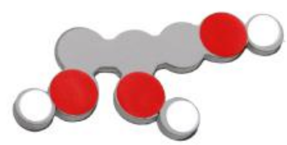
The building blocks of a phospholipid include two fatty acid tails, the glycerol backbone and a phosphate head. In this next activity you will model a dehydration synthesis reaction in the formation of a phospholipid.

1. Begin with one of the straight-chain fatty acids (saturated), the kinked-chain fatty acid (unsaturated), glycerol and one of the phospholipid heads as the reactants in this simulation.

Straight-Chain Saturated Fatty Acid (Trans Configuration)



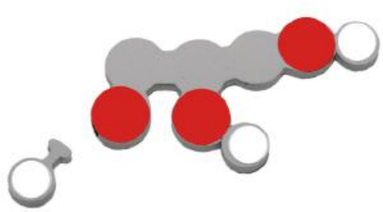
Kinked-Chain Unsaturated Fatty Acid (Cis Configuration)



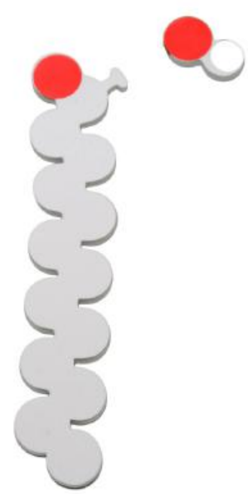
Glycerol

Phosphate Head (Phosphotidlycholine)

2. Remove one of the hydrogen (H) atoms from the glycerol.



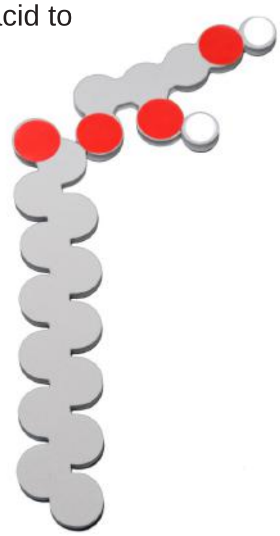
3. Remove the hydroxyl group (OH) from one of the straight fatty acids.



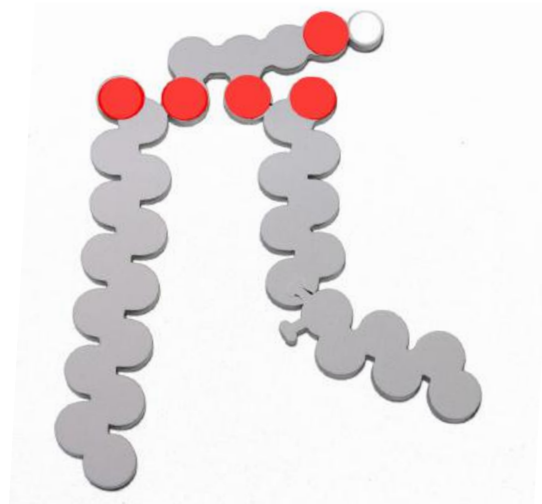
4. Combine the H and the OH.

Phospholipid Activity 1 Continued

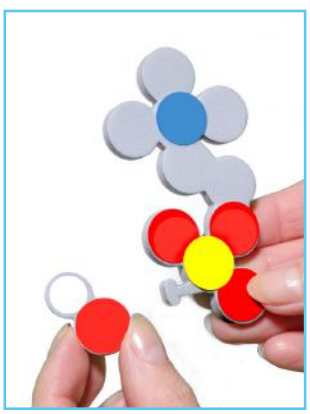
5. Join the fatty acid to the glycerol.

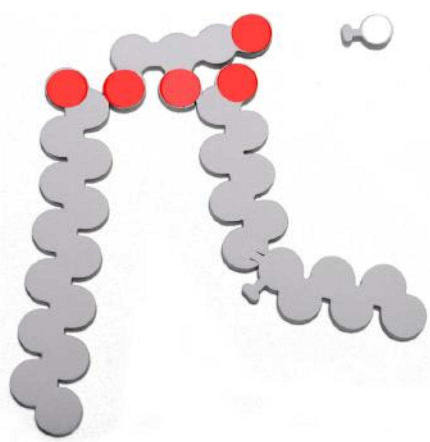


6. Repeat this process with the unsaturated fatty acid.



7. Remove the hydroxyl group from the phospholipid head and the final hydrogen (H) atom from the glycerol.

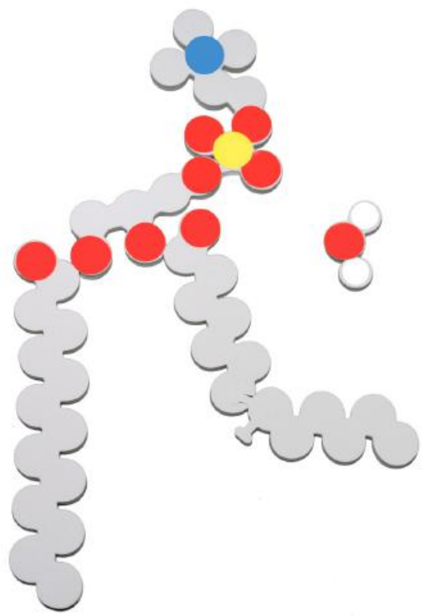




8. Combine each H with each OH.

Phospholipid Activity 1 Continued

9. Bind the phospholipid head to the glycerol backbone.



a. What type of reaction was used in the formation of your phospholipid?

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b. Remembering definitions of the terms **hydrophobic** and **hydrophilic,** deconstruct the word ***dehydration.***

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c. Define ***dehydration synthesis***.

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d. In the dehydration synthesis reactions you modeled, what parts did you combine to form a triglyceride and phosopholipid?

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e. How many water molecules did you synthesize? ______________________________

f. Compare and contrast dehydration synthesis of a triglyceride to a phospholipid.

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Phospholipid Activity 1 Continued

g. Sketch the specific structural formula of the phospholipid model you synthesized in the space provided below. Label the hydrophilic and hydrophobic regions of your structure.

Phospholipid Activity 1 Continued

h. Explain why you labeled the phospholipid parts as you did in your sketch on page 12.

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i. Compare your structure to that of the other groups in the room. Record any similarities you observe in these phospholipid structures.

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j. Based on these similarities a simplified representation may also be used to indicate phospholipid structure. Sketch a simple model in the space below. Label the hydrophobic and hydrophilic portions of this simplified model.

k. Record any differences in the specific structures you have observed between these phospholipids.

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Phospholipid Activity 1 Continued

There are four major phospholipids that comprise the plasma membrane. Phosphatidylcholine and sphingomyelin make up the outer leaflet layer of the membrane while phosphatidylethanolamine and phosphatidylserine make up the inner leaflet of the layer membrane. A fifth phospholipid, phosphatidylinositol, is also found in the inner leaflet layer of the plasma membrane. Although phosphatidylinositol is a minor membrane component, it plays a major role in cell signaling.

The general structure of a phospholipid is most often represented by the phosphatidylcholine structure: