Johns Hopkins Engineering

Molecular Biology

Membrane Characteristics and Composition

JOHNS HOPKINS
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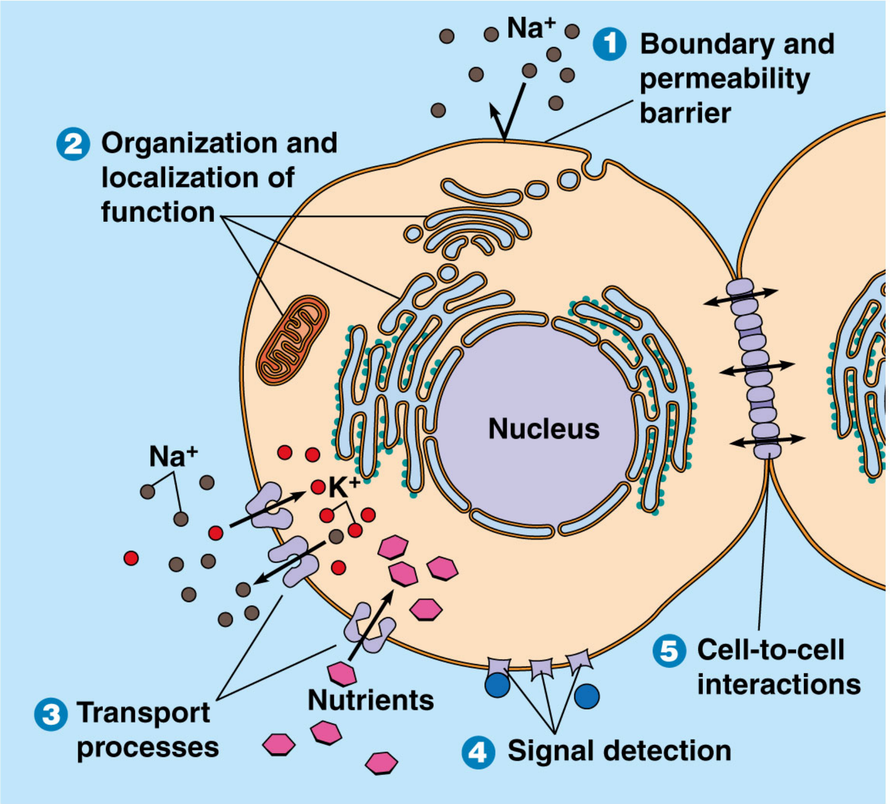
Outline

- Membrane:
  - Functions
  - Structure
  - Composition
  - Asymmetry
  - Fluidity

The Functions of Membranes



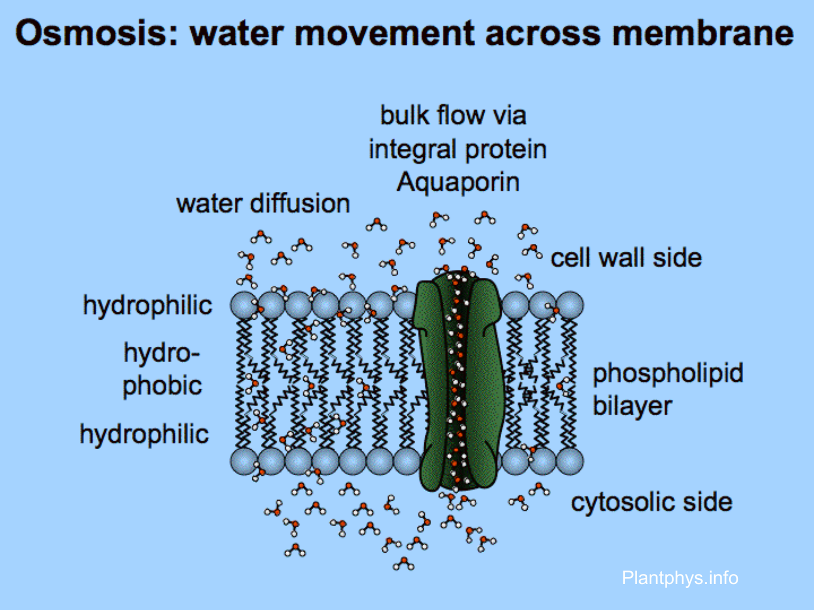
Membranes Are Sites of Specific Proteins and Specific Functions

- Membranes are associated with specific functions because the molecules responsible for the functions are embedded in or **localized** on membranes
  - Some membrane proteins are *enzymes*, which accounts for the localization of particular functions to specific membranes

- The specific enzymes associated with particular membranes can be used as *markers* to identify the membranes during isolation
  - Differential centrifugation
  - Immunostaining

Membrane Proteins Regulate the Transport of Solutes

- Cells and organelles take up nutrients, ions, gases, water, and other substances, and expel products and wastes
- Membrane proteins carry out and regulate the *transport* of substances across the membrane (e.g. aquaporin is an integral membrane protein that transports water)
- Some substances diffuse directly across membranes, whereas others must be moved by specific *transport proteins*



Membrane Proteins Detect and Transmit Electrical & Chemical Signals

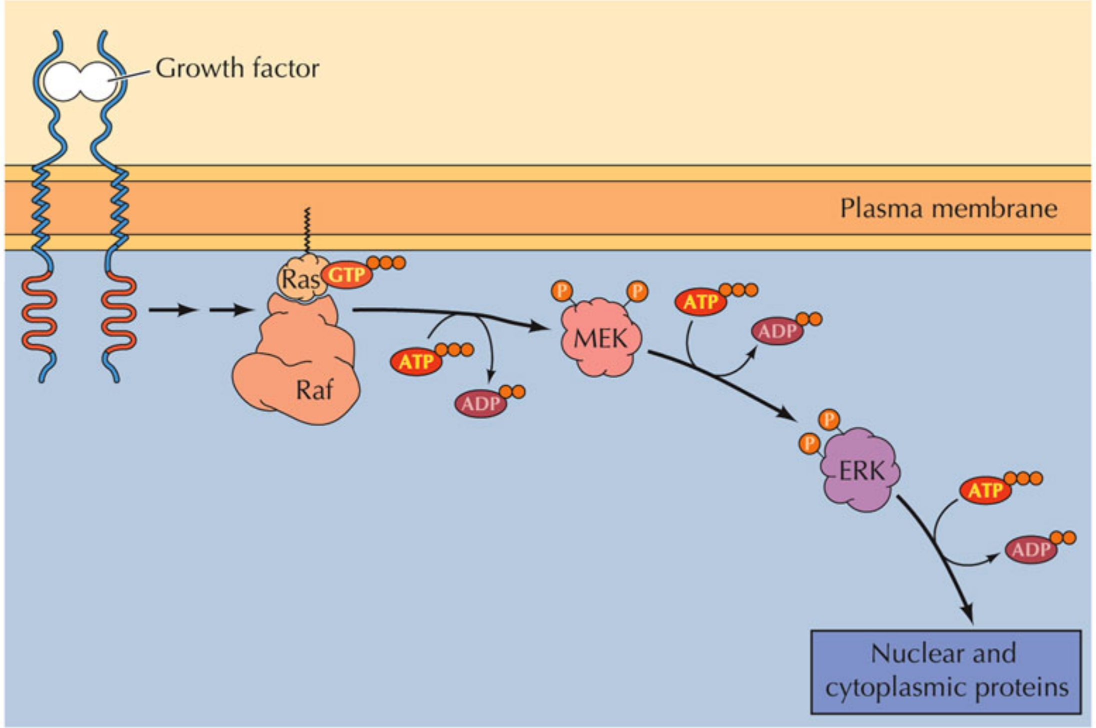
- A cell receives information from its environment as electrical or chemical signals at its surface

- **Signal transduction** describes the mechanisms by which signals are transmitted from the outer surface to the interior of a cell (e.g. receptor binding triggering changes in cell function)

  - Membrane receptors allow cells to recognize, transmit, and respond to a variety of specific signals in nearly all types of cells

- Chemical signal molecules usually bind to membrane proteins, *receptors*, on the outer surface of the plasma membrane

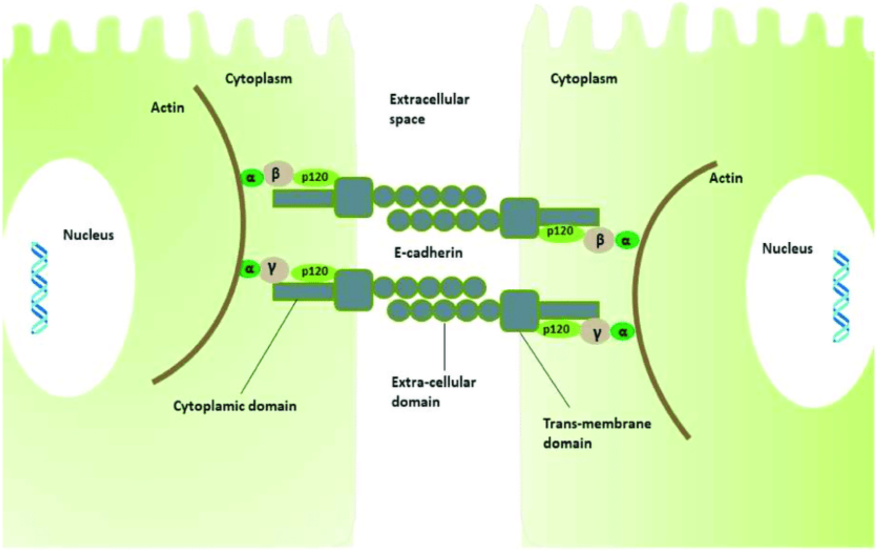
Signal transduction example…



THE CELL, Fourth Edition, Figure 15.34

Membrane Proteins Mediate Cell Adhesion and Cell-to-Cell Communication

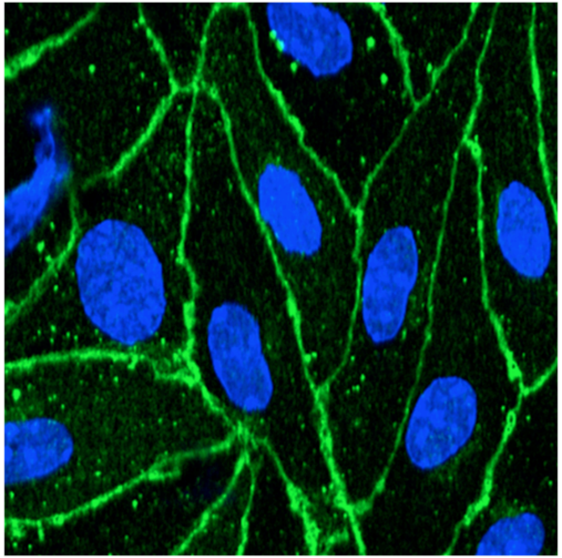
- Most cells in multicellular organisms are in contact with other cells
- Cell-to-cell contacts, critical in animal development, are often mediated by *cadherins*
- Cadherins have extracellular sequences of amino acids that bind calcium and promote adhesion between similar types of cells in a tissue



Ansari, et al. 2018.

Types of junctions between cells in animal tissues

- *Adhesive junctions* hold cells together
- *Tight junctions* form seals that block the passage of fluids between cells
- *Gap junctions* allow for communication directly between the cytoplasm of adjacent animal cells
  - In plants, *plasmodesmata* perform a similar function



Brain endothelial cells
green = occludin protein

Delaware Biotechnology Institute

Membrane proteins play roles in other cell functions

- Membrane proteins play roles in uptake and secretion of substances by endocytosis and exocytosis
- They also take part in targeting, sorting, and modification of proteins in the endoplasmic reticulum and Golgi complex
- They also participate in *autophagy*, the digestion of a cell's own organelles or structures

Membrane Structure: Fluid Mosaic Model

- The model envisions a membrane as two fluid layers of **lipids** with **proteins** within and on the layers (describes all biological membranes)
- The model has two key features
  - A *fluid* lipid bilayer
  - A *mosaic* of proteins attached to or embedded in the bilayer
- Membranes are
  - not homogenous, but freely mixing
  - ordered through dynamic microdomains called **lipid rafts**

Three classes of membrane proteins

- **Integral** membrane proteins are embedded in the lipid bilayer due to their hydrophobic regions
  - Most integral membrane proteins have one or more hydrophobic segments that span the lipid bilayer

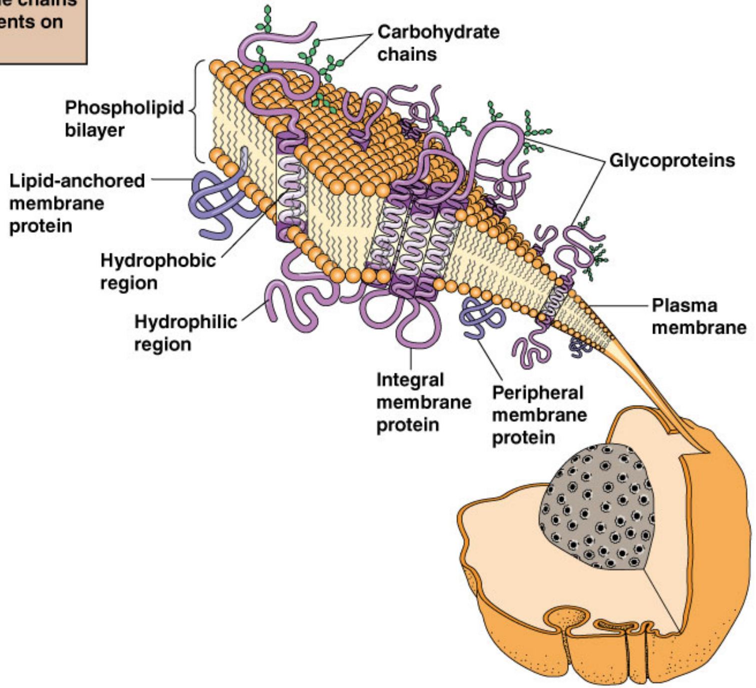
- **Peripheral** proteins are hydrophilic and located on the surface of the bilayer

- **Lipid-anchored** proteins are attached to the bilayer by covalent attachments to lipid molecules embedded in the bilayer

Most membrane proteins contain transmembrane segments which anchor the protein to the membrane

Integral Membrane Proteins

(b) An integral membrane protein with multiple α-helical transmembrane segments is shown below. Many integral membrane proteins of the plasma membrane have carbohydrate side chains attached to the hydrophilic segments on the outer membrane surface.



Membrane Lipids: The "Fluid" Part

- Membrane lipids are important components of the "fluid" part of the fluid mosaic model
- Membranes contain several types of lipids
- The fluid mosaic model of membrane structure retains the lipid bilayer of earlier models
- However, there is a greater diversity and fluidity of lipids than originally thought
- The main classes of membrane lipids are *phospholipids*, *glycolipids,* and *sterols*

https://www.youtube.com/watch?v=jM_xePC70Yo

Phospholipids

- **Phospholipids** are the most abundant lipids in membranes

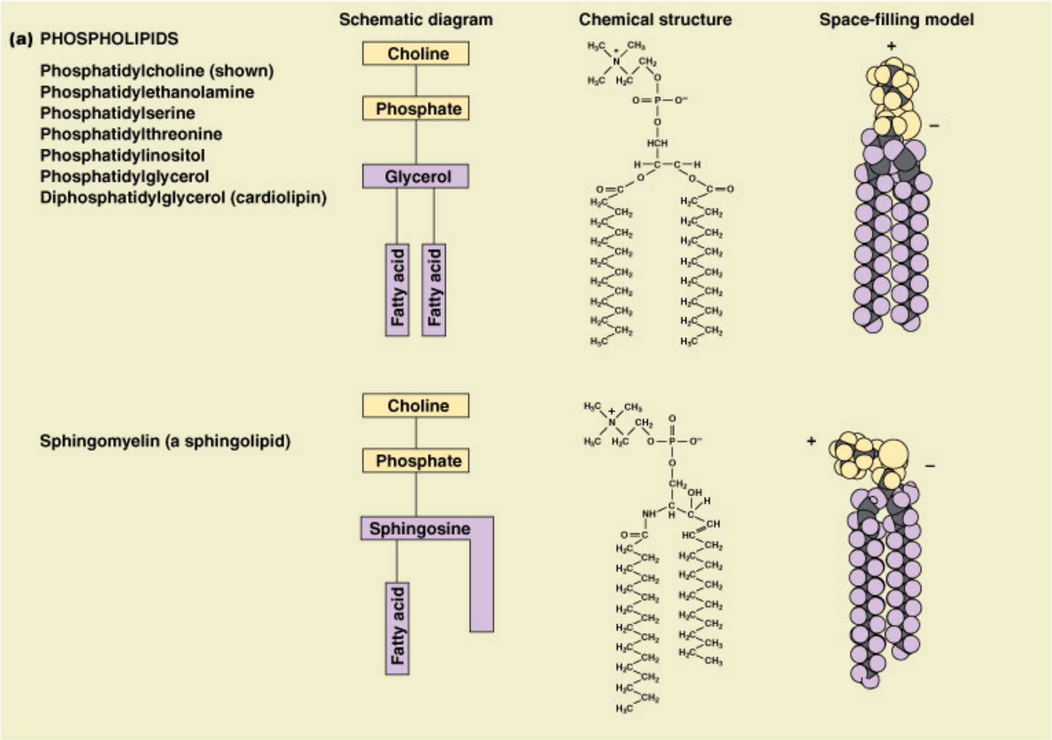
- They include the glycerol-based **phosphoglycerides** and the sphingosine-based **sphingolipids**

- The kinds and relative proportions of phospholipids vary greatly among types of membranes

- They are *amphipathic* and can form lipid bilayers

Phospholipids

Small polar head group, lipid backbone

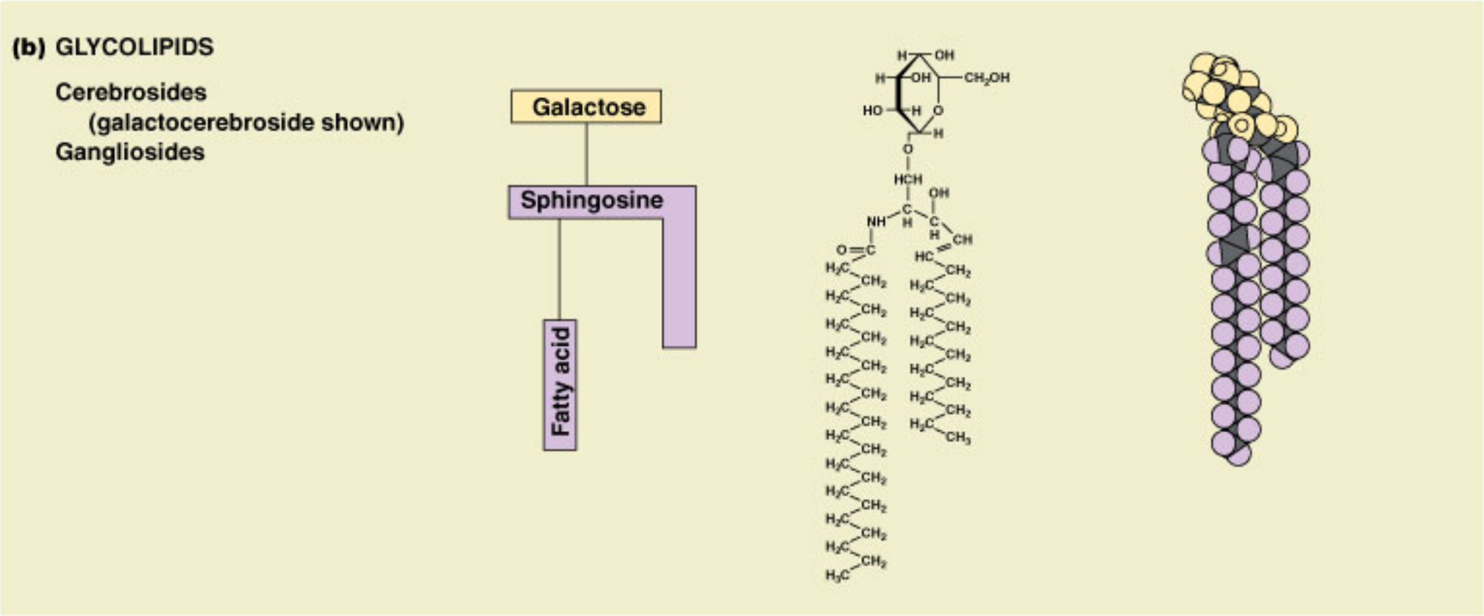


Glycolipids

- **Glycolipids** are formed by the addition of carbohydrates to lipids, and are typically on the extracellular-facing portion of the membrane
- Some are glycerol-based and some are sphingosine-based; the *glycosphingolipids*
- The most common glycosphingolipids are **cerebrosides** and **gangliosides**
- Main function is to maintain membrane stability and facilitate cell-cell communication

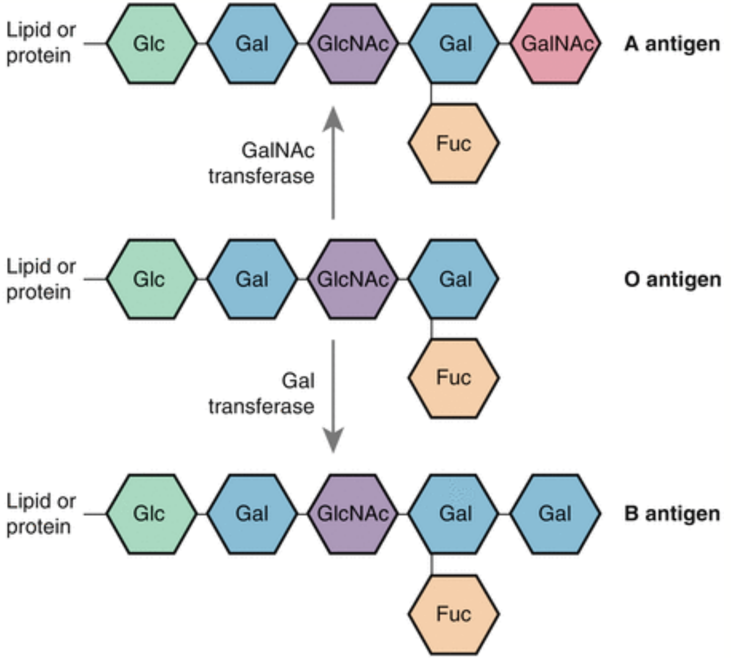
Glycolipids

Especially prominent in brain and nerve cells



Gangliosides

Gangliosides are expressed on the surface of the plasma membrane can be involved in <u>immune reactions</u> (e.g. ABO blood group antigens).



Glc=Glucose
Gal=Galactose
GlcNAc=*N*–Acetylglucosamine
GalNac=*N*–Acetylgalactosamine
Fuc=Fucose

Oh S. (2016) Gastric Cancer: ABO Blood Type. In: Kim N. (eds) Helicobacter pylori. Springer, Singapore

Sterols

- The membranes of most eukaryotes contain significant amounts of **sterols**
- The main sterol in animal cell membranes is **cholesterol,** which is needed to stabilize and maintain membranes
- **Cholesterol** adds firmness and integrity to the plasma **membrane** and prevents it from becoming overly fluid
- Plant cell membranes contain small amounts of **phytosterols**, whereas fungal cell membranes contain ergosterol, similar to cholesterol

Membrane Asymmetry: Most Lipids Are Distributed Unequally Between the Two Monolayers

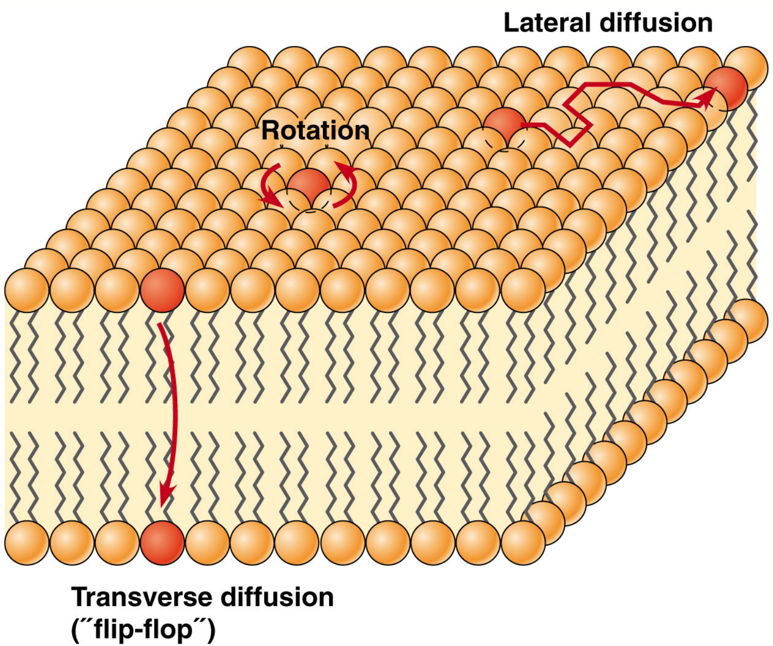
- Membrane asymmetry refers to the difference in the <u>kinds of lipids</u> and the <u>degree of saturation</u> of fatty acids in the phospholipids

- Membrane asymmetry is established during the synthesis of the membrane
  - Once established, membrane asymmetry does not change much (loss of asymmetry can indicate apoptosis)

- The movement of lipids from one monolayer to another requires their hydrophilic heads to move all the way through the hydrophobic interior of the bilayer

Lipids move freely within their monolayer

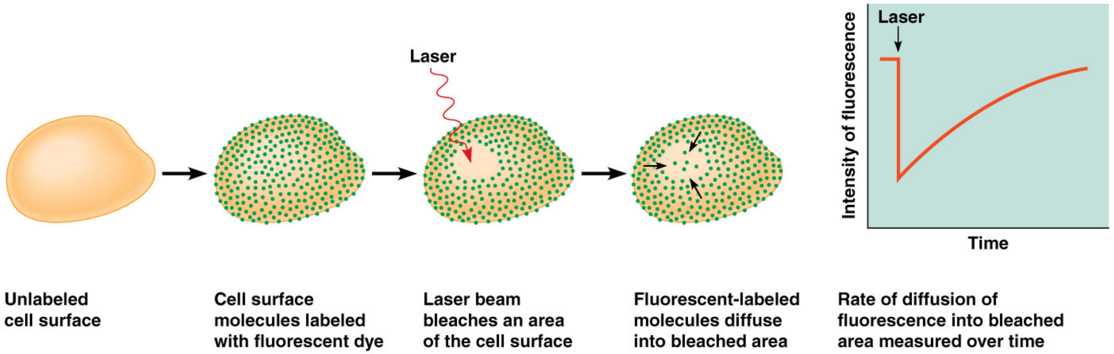
- Lipids are mobile within their monolayer
- **Rotation** of phospholipids about their axes can occur
- Phospholipids can also move within the monolayer, via **lateral diffusion**
- Both types of movement are rapid and random



How do we know this?

Measuring Membrane Fluidity

- The lipid bilayer permits the movement of both lipids and proteins
- Lipids can move as much as several μm per second within the monolayer
- Lateral diffusion can be demonstrated using **fluorescence recovery after photobleaching** (FRAP)



https://www.youtube.com/watch?v=CfRvmtBdZ9I

Membranes Function Properly Only in the Fluid State

- Membrane fluidity changes with temperature, decreasing as temperature falls and vice versa
- Every lipid bilayer has a characteristic **transition temperature T_m**, the temperature at which it becomes fluid
- This change of state is called a **phase transition**, in this case from solid to liquid
- Below the T_m, any functions that rely on membrane fluidity will be disrupted

Effects of Fatty Acid Composition on Membrane Fluidity

- Fluidity of a membrane depends mainly on the fatty acids that it contains
- The length of fatty acid chains and the degree of saturation both affect the fluidity of the membrane
- Long-chain and saturated fatty have higher T_ms, whereas short-chain and unsaturated fatty acids are more fluid than saturated fatty acids, and have lower T_ms
- Saturated fatty acids are “saturated” with hydrogen, and have no double bonds; They pack together well in the membrane

Summary

- Membrane:
    - Functions
    - Structure
    - Composition
    - Asymmetry
    - Fluidity

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