Chapter 7: Membrane Structure & Function

1. Membrane Structure
2. Transport Across Membranes

1. Membrane Structure

Chapter Reading – pp. 125-129

What are Biological Membranes?

They're basically a 2-layered sheet of phospholipids with some proteins & cholesterol.

Why phospholipids?
Because they are amphipathic – i.e., part is hydrophilic and part is hydrophobic.

They self-assemble spontaneously into a variety of organized structures, one of which is a lipid bilayer.
Hydrophilic head

Phospholipids

Hydrophobic tail

WATER

WATER

Phospholipids have a variety of polar head groups

Fluid

Unsaturated hydrocarbon tails

Viscous

Saturated hydrocarbon tails

Membrane Viscosity

(a) Unsaturated versus saturated hydrocarbon tails

(b) Cholesterol within the animal cell membrane

TEMPERATURE

higher temp = lower viscosity

SATURATION

more saturation of HC tails = more viscosity

CHOLESTEROL

increases viscosity at higher temp, prevents hardening at lower temp

Membrane Proteins

Membrane proteins may penetrate the interior of the membrane (integral) or interact with it externally (peripheral).

• the portions of a membrane protein that interact with the hydrophobic interior contain non-polar R groups

TECHNIQUE

FREEZE FRACTURE

EXTRACELLULAR SIDE

Plasma membrane

Cyttoplasmic layer

Knob

Proteins

RESULTS

Inside of extracellular layer

Inside of cytoplasmic layer

Inside of extracellular layer

Inside of cytoplasmic layer
**The Fluid Mosaic Model**

This model (hypothesis) proposes that proteins are scattered within a membrane and can move freely within the plane of the membrane.

- supported by the experiment shown below

**RESULTS**

MEMBRANE PROTEINS

Mouse cell + Human cell → Hybrid cell

Mixed proteins after 1 hour

***some proteins are "fixed" by attachment to cytoskeleton or ECM***

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**Model of Membrane Structure**

- Fibers of extracellular matrix (ECM)
- Glycoprotein
- Membrane proteins
- Peripheral proteins
- Integral proteins
- Cholesterol
- Carbohydrate
- Glycolipid
- EXTRACELLULAR SIDE OF MEMBRANE
- CYTOPLASMIC SIDE OF MEMBRANE

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**Main Roles of Membrane Proteins**

- Cell-cell recognition
- Intercellular joining
- Attachment to the cytoskeleton & ECM (extracellular matrix)
- Transport
- Enzymatic activity
- Signal transduction

These are the most common, though there are many other functions for membrane proteins.
Membrane Orientation

Membrane “Faces” are Different
While phospholipids move freely and rapidly within a given layer or “face”, they rarely switch layers.

• phospholipid composition of cytoplasmic vs extracellular face is different & is set up in the ER

2. Transport Across Membranes

Chapter Reading – pp. 129-138
Diffusion is the net or overall movement of a substance from higher to lower concentration

- molecules dissolved in liquid move randomly
- over time the net effect is equal dispersion of the molecules (provided there is no barrier)
- aka “moving down concentration gradient”

**Diffusion across a permeable barrier**

As long as there is nothing to block the passage of solutes, the 2 compartments will reach equilibrium

**Diffusion across a selectively permeable barrier**

The barrier allows water (solvent) to pass freely while the sugar (solute) cannot pass

- the net flow of water from [high] to [low] creates osmotic pressure on one side of the barrier

Osmosis is the diffusion of water across a selectively permeable membrane
Osmosis and Cells

(a) Animal cell
- Hypotonic solution: Water enters the cell, causing it to lyse.
- Isotonic solution: No net movement of water, cell remains normal.
- Hypertonic solution: Water exits the cell, causing it to shrink and become plasmolyzed.
(b) Plant cell
- Hypotonic solution: Water enters the cell, causing it to become turgid (normal).
- Isotonic solution: No net movement of water, cell remains normal.
- Hypertonic solution: Water exits the cell, causing it to become flaccid and plasmolyzed.

Combating Osmotic Pressure

Unicellular freshwater organisms that lack cell walls (such as many protozoa) are vulnerable to osmotic lysis (osmolysis).

Contractile vacuoles provide protection by taking on excess water and releasing it externally by exocytosis.

“Small-scale” Transport

Cells accomplish membrane transport on a “small scale” (molecule by molecule) in 3 basic ways:

1) passive transport (simple diffusion)
   - diffusion directly through the membrane bilayer

2) facilitated diffusion
   - diffusion with the help of specific membrane proteins

3) active transport
   - movement from low to high concentration
   - requires special membrane proteins and energy

Passive transport

Active transport

Diffusion
Facilitated diffusion
A TP
(a) A channel protein

Channel protein

Solute

CYTOPLASM

(b) A carrier protein

Carrier protein

Solute

Facilitated Diffusion

CHANNEL PROTEINS, some of which are gated, allow the passive transport of small molecules such as ions.

CARRIER PROTEINS bind to specific solutes and change conformation to release the solute on the opposite side.

- works both directions with overall movement from [high] to [low]

The Sodium-Potassium Pump

EXTRACELLULAR FLUID

Channel protein

Solute

CYTOPLASM

Carrier protein

Solute

Ion Transport & Membrane Potential

OUTSIDE

INSIDE

electrochemical gradient with no membrane potential

electrochemical gradient with membrane potential negative inside

electrochemical gradient with membrane potential positive inside

*cells normally have a negative membrane potential

Ion diffusion is driven by differences in concentration & charge across a membrane (electrochemical gradient).

- i.e., electrochemical gradient
**Cotransport**

Active Transport can be fueled by ATP or other energy-rich molecules, or by the cotransport of another molecule down its concentration gradient.

- this example shows how plants carry out the active transport of sucrose into vascular cells for distribution to the rest of the plant.
- ATP is still required for this process since it is used to set up the proton gradient sucrose transport depends on.

**“Large-scale” Transport**

Cells accomplish membrane transport on a “large scale” (in bulk) in 2 basic ways:

1) **exocytosis**
   - release of material packaged in membrane vesicles to the outside of a cell.

2) **endocytosis**
   - ingestion of large objects or large amounts of material by enclosing within a membrane vesicle:
     - PINOCYTOSIS
     - PHAGOCYTOSIS
     - RECEPTOR-MEDIATED ENDOCYTOSIS

**Exocytosis**

A general process for releasing material from a cell.
- e.g., neurotransmitters into a synapse, water from a contractile vacuole, antibodies from a B cell.
Phagocytosis ("cell eating")
Capture of large extracellular particles in vesicles.

- how many single-celled organisms feed (e.g., amoeba)
- how cells of the immune system destroy invaders

Pinocytosis ("cell drinking")
Capture of extracellular fluid in vesicles.
- a non-specific process of capturing solutes in the fluid immediately surrounding a cell

Receptor-mediated Endocytosis
A highly specific process of capturing substances in vesicles.
- receptors on the cell surface bind specific substances (receptor ligand)
- this triggers the formation of a coated pit which ultimately forms a vesicle transporting the receptor-ligand complex inside the cell
**Key Terms for Chapter 7**

- integral vs peripheral proteins, freeze fracture
- amphipathic, fluid mosaic model
- cytoplasmic & exoplasmic faces of membranes
- diffusion, osmosis, isotonic, hypertonic, hypotonic
- osmotic pressure, osmolyis, contractile vacuole
- passive transport, active transport, cotransport
- facilitated diffusion, electrochemical gradient
- carrier proteins, protein channels, pumps
- exocytosis, endocytosis, receptor-mediated end.
- vesicle, pinocytosis, phagocytosis

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**Relevant Chapter Questions 1-6**