Cell membrane (196 - 212) Chapter 8

8.1 Cellular membranes are fluid mosaics of lipids & Proteins

Membranes → Lipids → Phospholipids *** = amphipathic molecule
⊕ → hydrophilic (water-loving) region
↘ hydrophobic (water-fearing)

→ Proteins → Most are amphipathic molecule.

→ Carbohydrates

Fluidity of Membrane

Membrane
- not static & not locked rigidly
- held TGT by hydrophobic interaction weaker than covalent bond
- must be fluid to work properly.
  - as fluid as salad oil → too fluid → ✗ support prot⁻ func: → extreme enviroment → Evolutionary adaptation
  - fluidity affects
    - permeability
    - ability of memb: protein to move

Lipids & Proteins
- Lipids → Flip-Flop
- Proteins → Lateral diffusion ↗ (go sideways)
  - much larger
  - move slowly
  - s/t do drift
  - s/t move in a highly directed manner
  - s/t immobile (∵ attachment to cytoskeleton or ECM)

Lateral diffusion → rapid 2 μm/s

Temp ↓ (cool) ပေမဲ့ → fluid ဖြစ်လေ ← မဖြစ်စေဘဲ fluid အနေနဲ့ရှိ

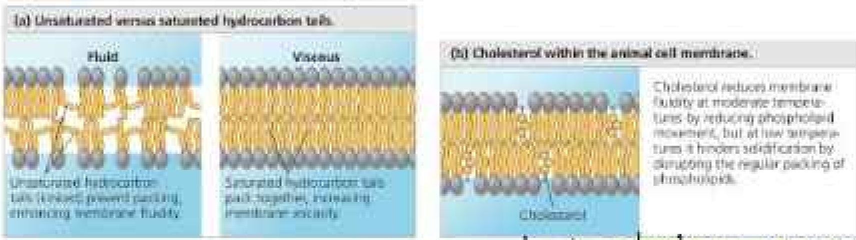
if PL closely packed together → membrane solidify

ဘယ် temp မှာ solidify ဖြစ်မလဲ type of lipid ပေါ်မူတည်

↓

- permeability changes
- memb: enzymatic proteins - inactive if their activity req: memb: m/m.

▼ Figure 8.5 Factors that affect membrane fluidity.



if PL is rich in unsaturated Hydrocarbon (hydrophobic region) tails → × packed closer TGT as saturated HC

kinks ⊕ → double bonds ⊕

↓

\> fluid

Steroid Cholesterol (wedge bet: PL molecules in plasma memb:)

(fluidity buffer) ← resist changing memb: fluidity that can caused by changes in temp:

37 °C (relatively ↑ temp: = human body temp:)

↓

less fluid → (restraining PL m/m)

▽ close packaging of PL → temp: လျော့ကျ → solidify ဖြစ်ပေ

Membrane Proteins & Their Functions

PL → main fabric of membrane

Protein → determines most of membrane's functions

cytoplasmic side of plasma memb: → cytoskeleton attachment ← Membrane Proteins → materials outside cells (fibers of ECM) ← ECM

Integral Proteins

- penetrate hydrophobic interior of lipid bilayer

Peripheral Proteins

- not embedded in lipid bilayer
- loosely bound to surface of memb:

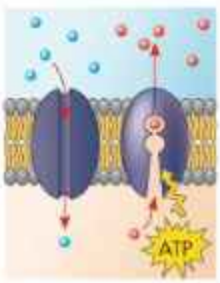
- majority - transmembrane proteins
  eg. Integrin
- other - extend only partway into hydrophobic interior

- hydrophobic region of IP
  ⊕ 1/> stretches of non-polar a/a
  (20 - 30 a/a) → coiled into α helices

- hydrophilic region of IP
  ↓
  exposed to equ: sol: of either side of memb:

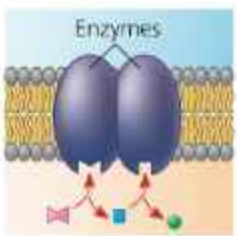
- some → + 1 | > hydrophilic channels

Functions of Membrane Proteins

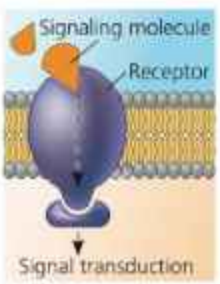


(a) Transport → hydrophilic channel
→ hydrolyze ATP & change shape to transport

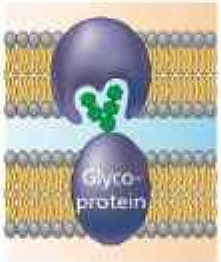
(b) Enzymatic activity → protein itself is an enz: & its active site (reactant combines here)



(c) Signal transduction → protein itself is a receptor & a binding site that fits a chemical messenger (Hlm)
↓ change shape
relay msg inside of the cell
by binding to a cytoplasmic protein.

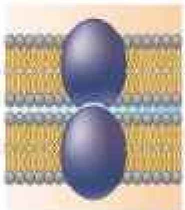


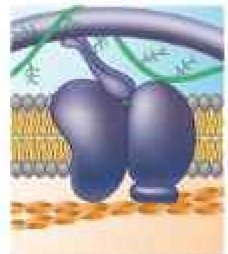
(d) Cell-Cell recognition = cell to cell binding



Glycoproteins = ID tags
↓
recog: by memb: of cells → binding (short-lived)

(e) Intercellular joining = Gap junctions, tight junctions binding (More long lasting)





(f) Attachment to cytoskeleton & extracellular Matrix

- cytoskeleton ၏ microfilament / other elements
  ↓ memb: prot ၏ non-covalently bind → maintain cell shape
  ↘ stabilize location of memb: prot

- ECM molecules ၏ bind → can coordinate extracellular & intracellular changes

Relevant in life

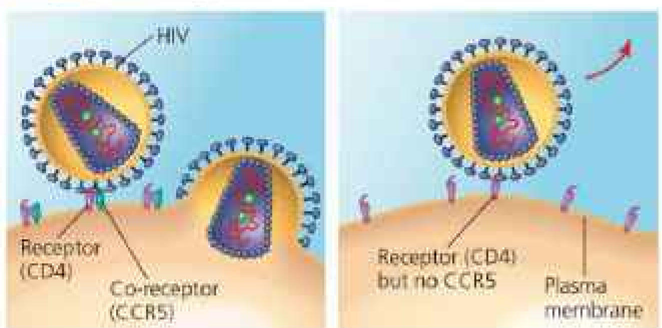
Immune cell's memb: protein
↓
CD4 (main r(c)) ၏ CCR5 (co-receptor) + HIV → infect the cells → AIDS

Dangerous S/E ⊕
∵ CD4 က #func: % ကြီး လုပ်ပေးလို့

virus က cell ထဲ ဝင်လေ့ရှိ:

↑ mask CCR5 & ▽ HIV entry
Maraviroc

Figure 8.8 The genetic basis for HIV resistance.



(a) HIV can infect a cell with CCR5 on its surface, as in most people.
(b) HIV cannot infect a cell lacking CCR5 on its surface, as in resistant individuals.

Role of Membrane carbohydrates in Cell-Cell Recognition

Cell-Cell recognition = cell's ability to distinguish 1 type of neighbouring cells from another

↓

* in func: of organism

eg. embryo - sorting of cells

* line of defense - basic for rejection of foregin cells by immune sys:

recognition is done by

↓

by binding to molecules often containing CHO on extracellular surface of plasma memb

=

Membrane Carbohydrates - short, branched chains of < 15 sugar units

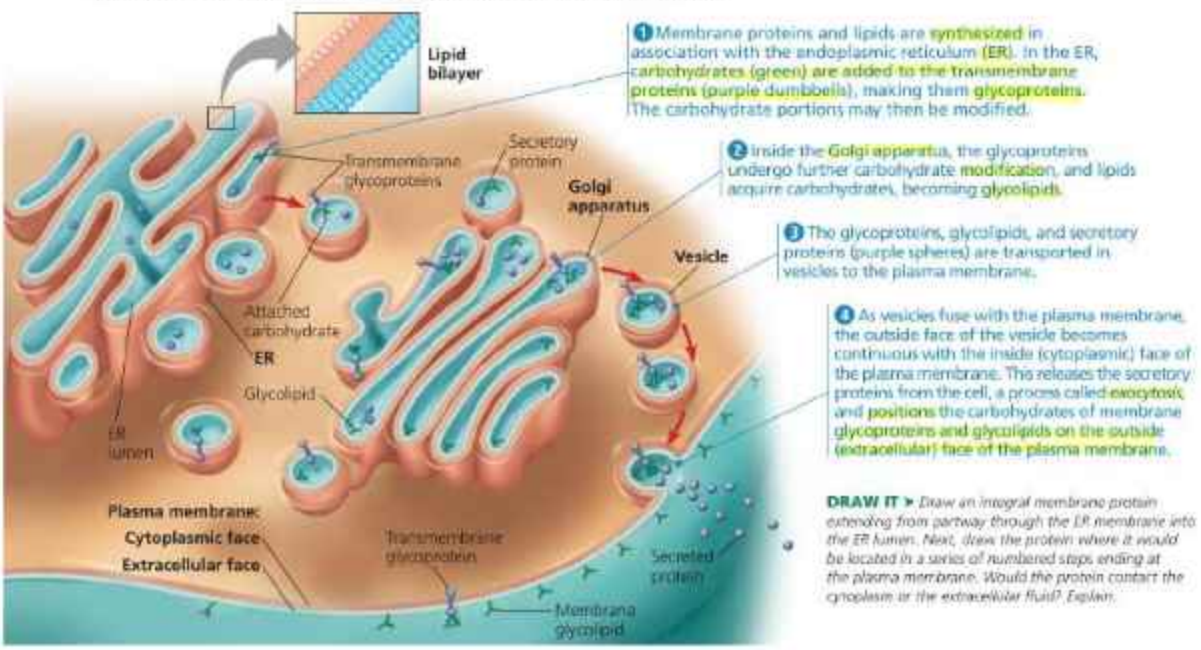
to lipid ← covalently bind → to protein

Glycolipids — Glycoproteins

Relevent in Life → Bld gp A, B, AB, O ∵ diff variation in CHO part of Glycoprotein on surface of RBCs

Synthesis of membrane → ER & Golgi Apparatus

Figure 8.9 Synthesis of membrane components and their orientation in the membrane. The cytoplasmic (orange) face of the plasma membrane differs from the extracellular (aqua) face. The latter arises from the inside face of ER, Golgi, and vesicle membranes.



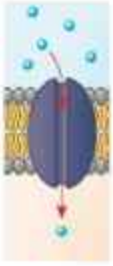
8.2 Membrane structure results in selective permeability

Permeability of the Lipid Bilayer

Non-polar molecules, Lipids (hydrocarbons, CO_2, O_2) ⇒ hydrophobic ⇒ dissolve in lipid Bilayer
↓
cross it easily w/o hp of memb: proteins

Polar molecules, ions (water) ⇒ hydrophilic ⇒ hydrophobic interior of lipid Bilayer
↓
direct passage
× cross rapidly

Cell's selective permeability → Lipid Bilayer +
↘ Membrane Proteins (key role in transport)
Transport



Transport Proteins

Channel proteins

- hydrophilic channel as a tunnel

eg. Aquaporins

each aquaporin entry → 3 billion (3×10^9) water molecules per second

Carrier proteins

- hold onto their passenger & change shape in a way that shuttles them across membrane

eg. Glucose transporter (so selective)
even rejects fructose
(structural isomer of glucose)

Passive transport is diffusion of a substance across a membrane with no energy investment

Molecules -> + constant motion -> + thermal energy

↓

Diffusion = Movement of particles of any substance so that they spread out into the available space (random)

e.g. a synthetic membrane (permeable) separating pure water from a solution of dye in water

↓

diffusion occur → equal concentration of dye molecules = reach to dynamic equilibrium = many dye molecules cross the membrane in one direction as in the other

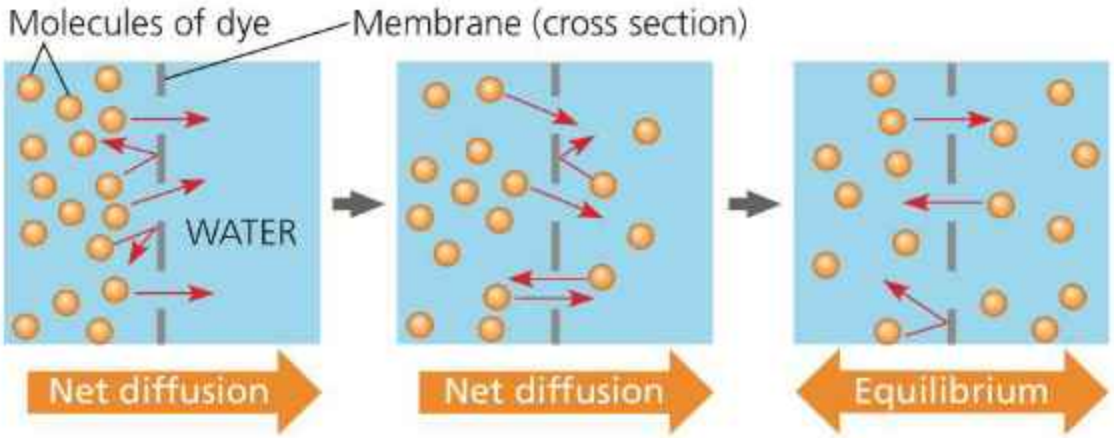
Diffusion = In the absence of other forces, a substance will diffuse from where it is more concentrated to where it is less concentrated. (along its concentration gradient)
-> Membrane should be selectively permeable
-> No work must be done to make this happen
-> Spontaneous process
-> No input of energy needed
-> unaffected by conc gradient of other substances

Concentration gradient = region along which density of a chemical substance increases or decreases
-> CG itself represent POTENTIAL ENERGY & drive DIFFUSION

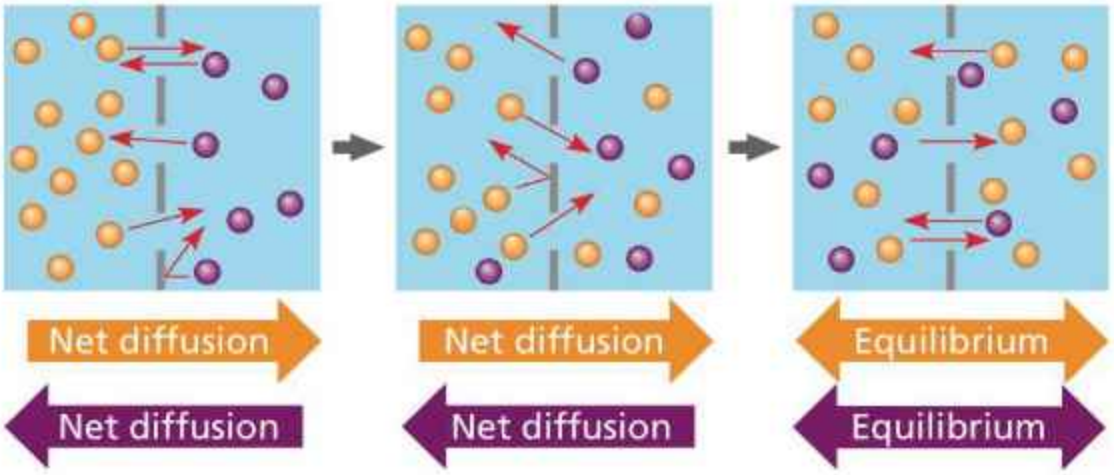
e.g uptake of O2 by a cell performing cellular respiration
(Dissolved O2 diffuses into cell across plasma membrane)

Passive transport = Diffusion of a substance across a biological membrane (bc cells do not need to expend energy)

Figure 8.10 The diffusion of solutes across a synthetic membrane. Each of the large arrows under the diagrams shows the net diffusion of the dye molecules of that color.



(a) Diffusion of one solute. The membrane has pores large enough for molecules of dye to pass through. Random movement of dye molecules will cause some to pass through the pores; this will happen more often on the side with more dye molecules. The dye diffuses from where it is more concentrated to where it is less concentrated (called diffusing down a concentration gradient). This leads to a dynamic equilibrium: The solute molecules continue to cross the membrane, but at roughly equal rates in both directions.



(b) Diffusion of two solutes. Solutions of two different dyes are separated by a membrane that is permeable to both. Each dye diffuses down its own concentration gradient. There will be a net diffusion of the purple dye toward the left, even though the *total* solute concentration was initially greater on the left side.

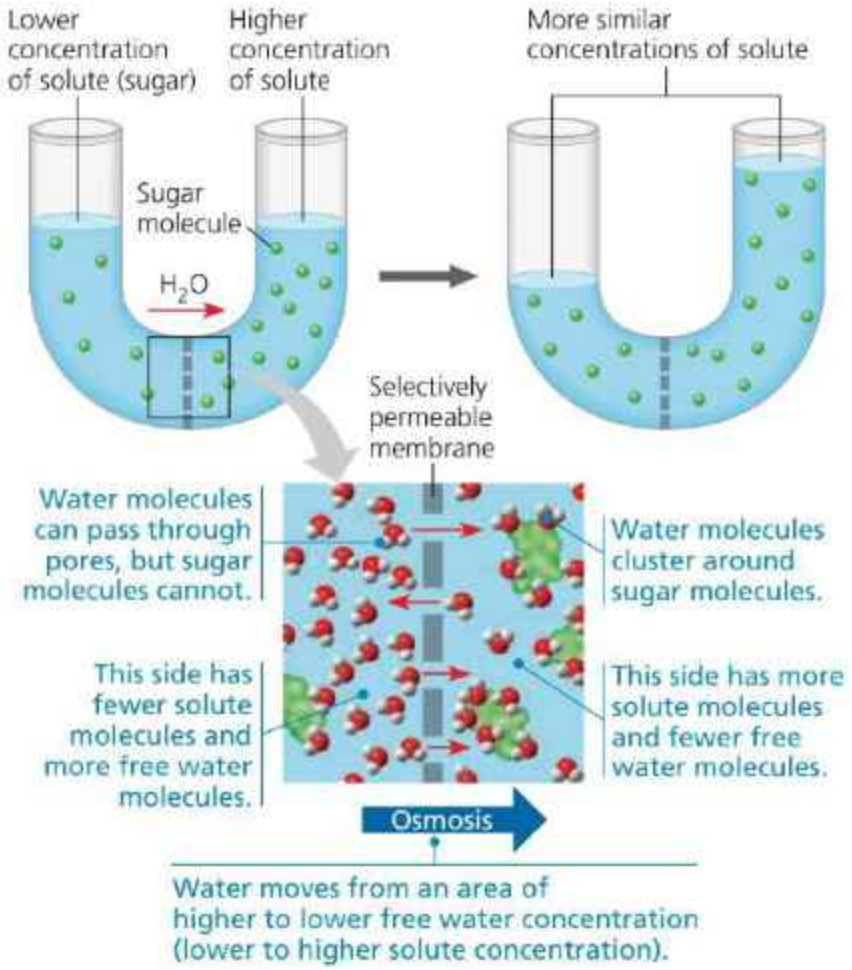
Effects of Osmosis on Water Balance

e.g.Two sugar solution of different solute concentrations are separated by a selectively permeable membrane that only solvent(Water) can pass through but the solute(sugar)cannot.(bcuz pores in the membrane are only large enough for water molecules)

-> Water molecules move randomly in both direction
-> tight clustering of water molecules around hydrophilic solute molecules --> some water unavailable to cross membrane
-> thus, solution with a higher solute concentration -> + lower free water molecules
-> Water diffuses from region of higher free water conc:(Lower solute conc:) to Lower free water conc:(higher solute conc:) until SOLUTE CONC: ON EACH SIDE ARE MORE NEARLY EQUAL
-> but overall water diffuses from solution with less conc: solute --> more conc: solute

not exactly equal (dil effect of H_2O on higher side)

= PASSIVE TRANSPORT OF WATER(OSMOSIS) -> make sugar conc: on both sides more nearly equal



OSMOSIS = Diffusion of free water across a selectively permeable membrane whether artificial or cellular

Application of osmosis to living cells

Water Balance of cells without cell walls

For behavior of cell in a solution,
--> we must consider both --> SOLUTE CONC & MEMB PERMEABILIY

TONICITY = ability of a surrounding solution to cause a cell to gain or lose water
-> Tonicity of a solution dp on --> its solute conc: that cannot cross membrane relative to that inside the cell
E.g. higher solute conc: in surrounding solution --> WATER WILL LEAVE THE CELL and vice versa

If cells without a cell wall(s/a animal cell) -> immersed in ISOTONIC environment
↓
NO NET MOVEMENT OF WATER
-> animal cell volume is stable

↓
cannot tolerate excessive uptake or loss of water
↓
so to live in hypertonic/ hypotonic environment
↓
must have OSMOREGULATION
(Control of solute conc: and water balance)

Thus, Seawater is isotonic to many marine invertebrates.
And ECF(extracellular fluid) is isotonic to the cells of land-dwelling animals.

e.g. Unicellular Eukaryote Paramecium → live in pond water(hypotonic)
(+ plasma memb: that is much less permeable to water -> that slows uptake of water into the cell)
↓
Cell doesn't burst
(bcuz of contractile vacuole = organelle that func: as a bilge pump to force water out of th cell as fast as it enters by osmosis)

If cells without a cell wall(s/a animal cell) -> immersed in HYPERTONIC environment
↓
CELL WILL LOSE WATER ⟶ SHRIVEL AND DIE
increase in salinity of a lake can kill animals

Bacteria and archaea that live in hypersaline environments -> + cellular mechanisms that balance internal and external solute conc: to ensure that water does not move out of the cell

If cells without a cell wall(s/a animal cell) -> immersed in HYPOTONIC environment
↓
WATER WILL ENTER THE CELL FASTER THAN IT LEAVES ⟶ CELL SWELLING AND BURST(LYSE)

Figure 8.13 The contractile vacuole of *Paramecium*. The vacuole collects fluid from canals in the cytoplasm. When full, the vacuole and canals contract, expelling fluid from the cell (LM).

Water Balance of Cells with Cell Walls

Cells of Plants
Prokaryotes
Fungi
Some Unicellular Eukaryotes
→ + cell wall → immersed in HYPOTONIC SOLUTION (s/a rainwater)

↓

cell wall helps maintain cell's water balance
-> Relatively inelastic cell wall will expand only much before it exerts a back pressure on the cell (TURGOR PRESSURE) -> Oppose further water intake

↓

Cells become TURGID(very firm) = healthy state for most plant cells

Plants that are not woody(s/a houseplants) --> dp on cell turgidity by a surr: hypotonic sol: for mechanical support

If immersed in ISOTONIC SOLUTION (s/a rainwater)

↓

NO NET TENDENCY FOR WATER TO ENTER

↓

Cells become FLACCID(limp) => plants will wilts

If immersed in HYPERTONIC SOLUTION

↓

Cells will LOSE WATER AND SHRINK

↓

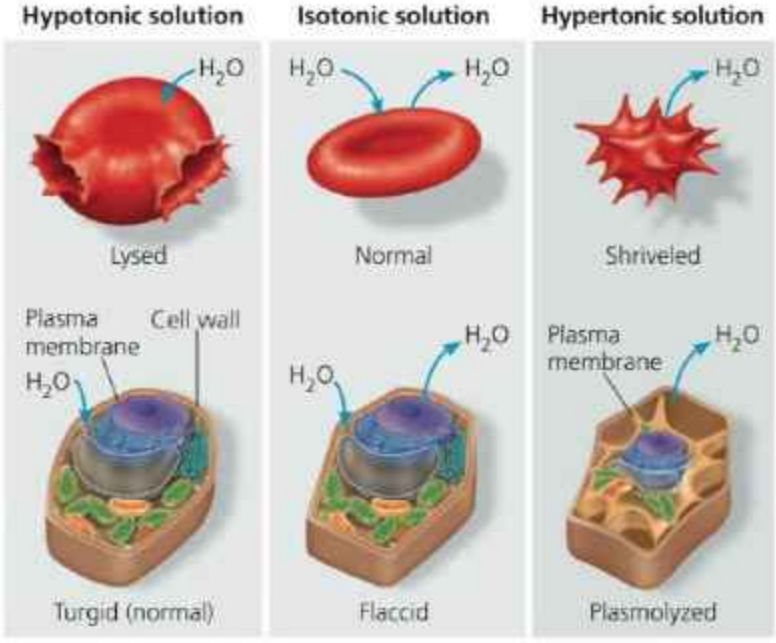
As plant cell shrivels --> PLASMOLYSIS occur (plant cell plasma memb: pulls away from cell wall at multiple places

↓

Plant will wilt and DIE

Active transport uses energy to move solutes against their gradients

Figure 8.12 The water balance of living cells. How living cells react to changes in the solute concentration of their environment depends on whether or not they have cell walls. **(a)** Animal cells, such as this red blood cell, do not have cell walls. **(b)** Plant cells do have cell walls. (Arrows indicate net water movement after the cells were first placed in these solutions.)



Facilitated Diffusion: Passive Transport aided by Proteins

Many polar molecules and ions --> impeded by lipid bilayer of memb:

↓ (FACILITATED DIFFUSION)

Diffuse passively with the help of transport proteins that span the membrane
(very specific)

↙ ↘

Channel Proteins | **Carrier Proteins**

↙ ↘ | ↓

AQUAPORIN

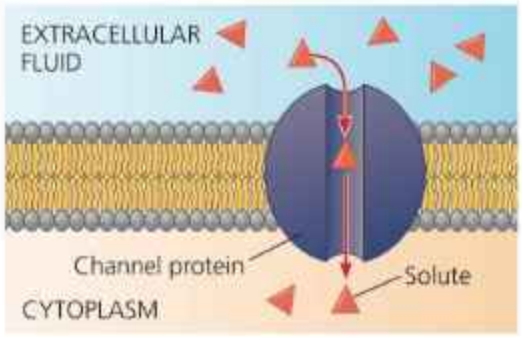
facilitate massive levels of water diffusion(OSMOSIS)
->in plant cells and in RBCs
->in kidney cells --> to reclaim water from urine
(without this -> you will excrete 180 L of urine/Day and have to drink equal amoun of water)

ION CHANNEL (GATED CHANNEL)

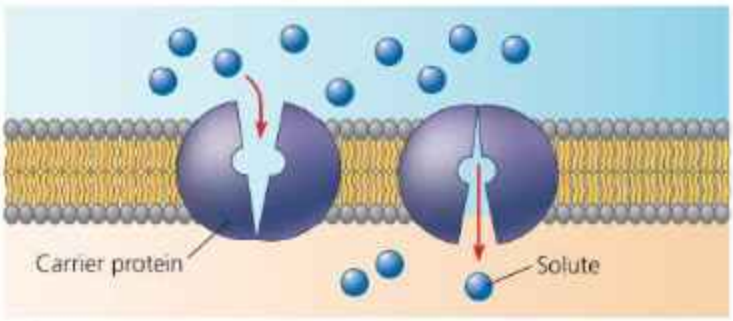
-> Open or close when a specific substance other than the one to be transported binds to the channel in response to a stimulus (m/b electrical stimulus)

GLUCOSE TRANSPORTER)

Binding and release of transported molecule
↓
change in shape
↓
translocates the solute-binding site across the membrane
↓
Net m/m of sub: down its conc: gradient



(a) A channel protein has a channel through which water molecules or a specific solute can pass.



(b) A carrier protein alternates between two shapes, moving a solute across the membrane during the shape change.

Active transport uses energy to move solutes against their gradients

The Need for Energy in Active Transport

To pump a solute across a membrane against its gradient (ACTIVE TRANSPORT)
-> requires work
-> the cell must expend energy
-> all carrier proteins rather than channel proteins
-> Active transport enables a cell --> to maintain internal concentrations of small solutes that differ from concentrations in its environment

e.g. Compared with its surroundings, animal cell --> (+) a much higher conc: of (K^+) ions & a much lower conc: of (Na^+) ions

$K^+ \downarrow$
$Na^+ \uparrow$

↓

Plasma membrane helps maintain these steep gradients
by pumping Na+ out of the cell
and K+ into the cell.

↓ ATP hydrolysis

ATP transferred its terminal Phosphate directly to transport protein

↓

induce the protein to change its shape

↓

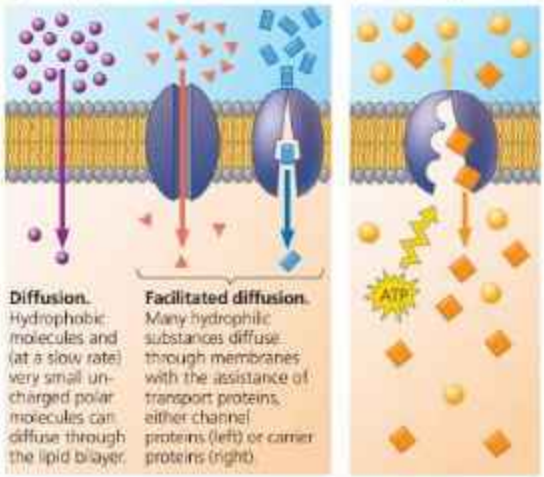
in a manner that translocates a solute bound to the protein across the membrane.

e.g. sodium-potassium pump, which exchanges Na+ for K+

Figure 8.16 Review: passive and active transport.

Passive transport. Substances diffuse spontaneously down their concentration gradients, crossing a membrane with no expenditure of energy by the cell. The rate of diffusion can be greatly increased by transport proteins in the membrane.

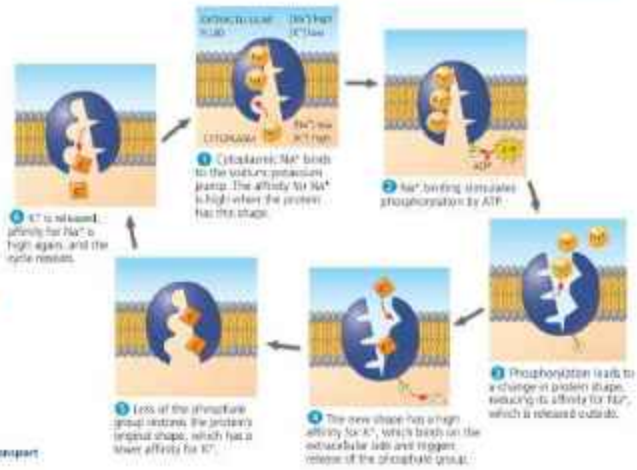
Active transport. Some transport proteins act as pumps, moving substances across a membrane against their concentration (or electrochemical) gradients. Energy is usually supplied by ATP hydrolysis.



Diffusion. Hydrophobic molecules and (at a slow rate) very small uncharged polar molecules can diffuse through the lipid bilayer.

Facilitated diffusion. Many hydrophilic substances diffuse through membranes with the assistance of transport proteins, either channel proteins (left) or carrier proteins (right).

Figure 8.15 The sodium-potassium pump: a specific case of active transport.



Animation: Active Transport

How Ion Pumps Maintain Membrane Potential

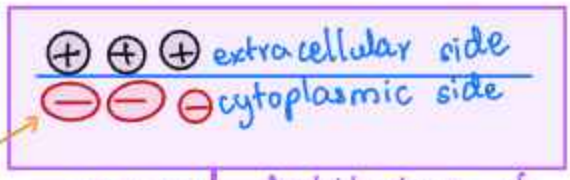
membrane potential

All cells -> + voltage across their plasma membrane

↓ =

Electrical potential energy
(a separation of opposite charges)

-50 to -200 milliV
↘ inside of cell is relatively negative



unequal distribution of anions & cations on 2sides

↓

MP favours
passive transport of cations into cells
& anions out of cells

Like a battery (an energy source that affects the traffic of all charged substances across the membrane)

In the case of ions, IONS diffuse down its electrochemical gradient. .

2 forces that drive diffusion of ions across a membrane (ELECTROCHEMICAL GRADIENT)

1. Chemical force (ion's concentration gradient)
2. Electrical force (effect of the membrane potential on the ion's movement)

The 2 forces will not always act in same direction
(s/t when electrical forces might oppose simple diffusion of ion down its conc: gradient)

↓

ACTIVE TRANSPORT MAY BE NEEDED

Some membrane proteins --> actively transport ions -> to contribute to memb: potential

e.g. sodium-potassium pump -> pumps 3Na+ out of the cell
-> pumps 2K+ into the cell

major EG pump of animal cells

-> Net transfer of 1(+) charge to ECF

↓

ELECTROGENIC PUMP = transport protein that generates voltage across memb: ← This process stores energy as voltage

↓

can be used for cellular work

e.g. Proton pump(H+ out) <- Main EG pump of plants,fungi and bacteria

↓

*use = ATP synthesis during cellular respiration

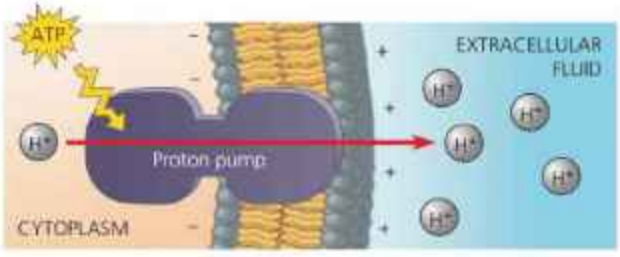


Figure 8.17 A proton pump. Proton pumps are electrogenic pumps that store energy by generating voltage (charge separation) across membranes. A proton pump translocates positive charge in the form of hydrogen ions. The voltage and H^+ concentration gradient represent a dual energy source that can drive other processes, such as the uptake of nutrients. Most proton pumps are powered by ATP hydrolysis.

Cotransport: Coupled Transport by a Membrane Protein

COTRANSPORT = a transport protein (a cotransporter) can couple the "downhill" diffusion of the solute to the "uphill" transport of a second substance against its own concentration gradient.

e.g. proton pump (powered by ATP Hydrolysis) --> H+ out of the cell

↓

increase in H+ conc: outside cell(H+ gradient)

↓ H+/Sucrose cotransporter

Cotransporter couples diffusion of H+ to cell with active transport of sucrose into cell of veins of leaves (against its conc: gradient) .

↓

distribute sugar to roots and other nonphotosynthetic organs that do not make their own food

Plant cell use proton pump to drive active transport of amino/a, sugars or several nutrients into the cell.

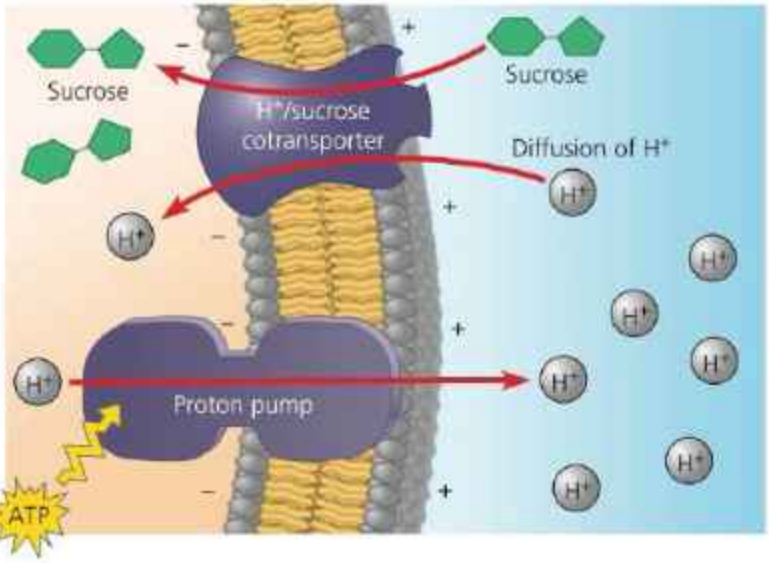


Figure 8.18 Cotransport: active transport driven by a concentration gradient. A carrier protein, such as this H^+/sucrose cotransporter in a plant cell (top), is able to use the diffusion of H^+ down its electrochemical gradient into the cell to drive the uptake of sucrose. (The cell wall is not shown.) Although not technically part of the cotransport process, an ATP-driven proton pump is shown here (bottom), which concentrates H^+ outside the cell. The resulting H^+ gradient represents potential energy that can be used for active transport—of sucrose, in this case. Thus, ATP hydrolysis indirectly provides the energy necessary for cotransport.

Cotransport proteins in animal cells => more effective Tx for Diarrhoea

Diarrhoea -> expels waste rapidly

Normally, Na+ in waste --> reabsorbed in colon maintaining constant level in body

↓

Na+ level falls

Tx = Drink high conc: of salt(NaCl) and glucose -> solutes are taken up by Na+/Glucose cotransporters on surface of intestinal cells --> into blood --> lower infant mortality rate

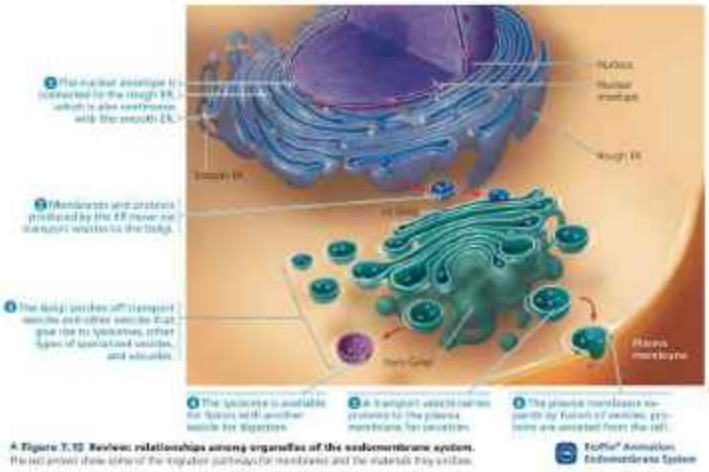
Bulk transport across the plasma membrane occurs by exocytosis and endocytosis

Water and small solutes --> enter and leave cells by diffusion/by pumps/ or by transport protein

Larger molecules(s/a proteins, polysaccharides) --> cross memb: in bulk,packed in vesicles
require energy

EXOCYTOSIS

Transport vesicle with secretory substance -> budded from Golgi apparatus
and moves along microtubules of cytoskeleton
to plasma membrane



↓

Vesicle memb: touch with plasma membrane

↓

Specific proteins rearrange lipid molecules
of two bilayers

↓

Two membrane fuses

↓

Contents of vesicle spill out of the cell
vesicle memb: becomes part of plasma memb:

EXOCYTOSIS = cell secretes certain molecules by fusion of vesicles with the plasma memb:

e.g. Insulin secretion from pancreas into ECF
N/T release from neurons to signal muscle cells
Exocytosis delivers some necessary proteins and CHOs from Golgi vesicles to outside of cells to make cell walls in plant cells

ENDOCYTOSIS

ENDOCYTOSIS = the process how cell takes in molecules and particulate matter by forming new vesciles from plasma membrane

A small area of plasma memb: sink inward
↓
form pocket
↓
pocket deepens --> pinches in
↓
form vesicle containing material

3 types of ENDOCYTOSIS
Phagocytosis(cellular eating)
Pinocytosis(cellular drinking)
Receptor-mediated endocytosis

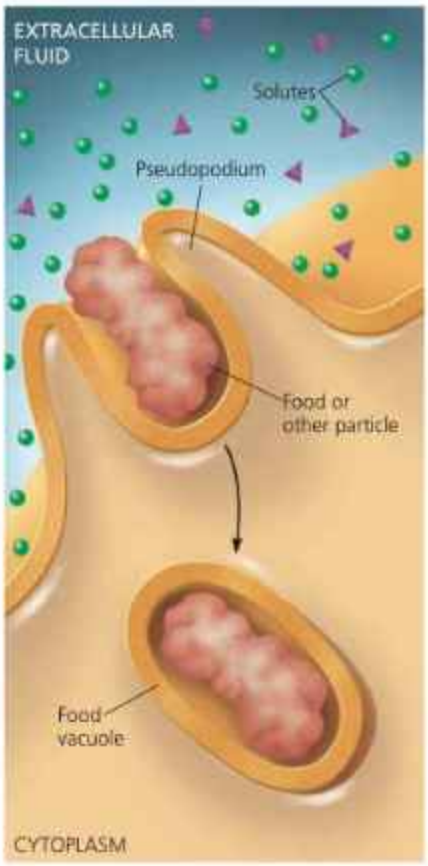
Human cells use r/c mediated endocytosis
to take in CHOLESTEROL for memb: syn: & syn: of other steroids
↓
Cholesterol travels in blood in particles called LDL(low density lipoprotein)
↓
LDL bind to LDL r/c on plasma membrane → defective / missing in inherited dis familial hypercholesterolemia
↓
enter the cells by endocytosis

(∴ ↑ bld cholesterol)
↓
early atherosclerosis
↓
♡ damage / stroke

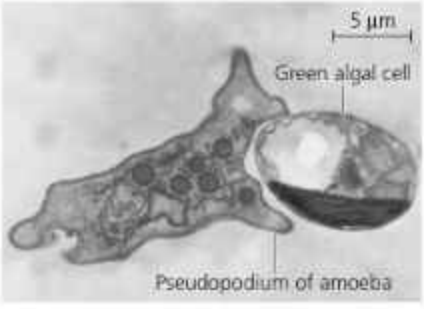
Endocytosis and exocytosis also provide mechanisms for rejuvenating or remodeling the plasma membrane.
occur in most eukaryotic cells
amount of plasma memb: in nongrowing cell => remains fairly constant
(bcuz addition of memb: appears to offset the loss of membrane by other.

Figure 8.19 Exploring Endocytosis in Animal Cells

Phagocytosis

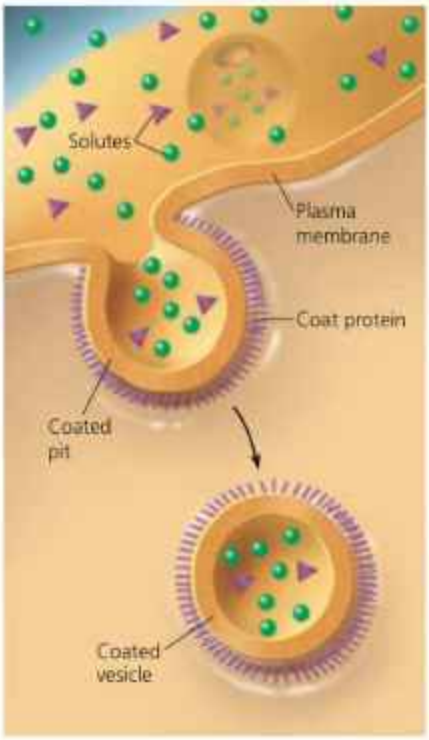


In **phagocytosis**, a cell engulfs a particle by extending pseudopodia (singular, *pseudopodium*) around it and packaging it within a membranous sac called a food vacuole. The particle will be digested after the food vacuole fuses with a lysosome containing hydrolytic enzymes (see Figure 7.13).

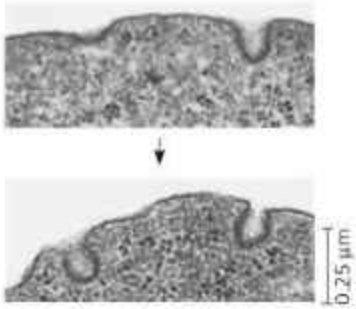


An amoeba engulfing a green algal cell via phagocytosis (TEM).

Pinocytosis

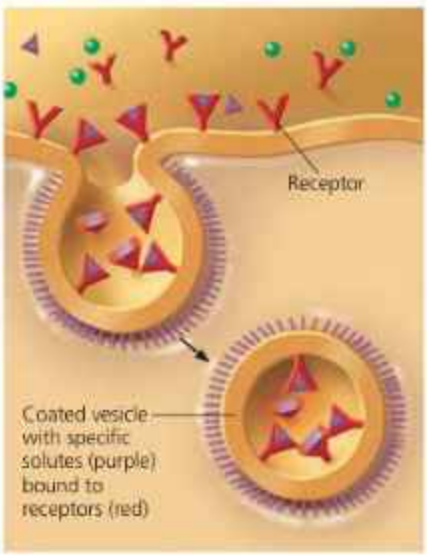


In **pinocytosis**, a cell continually "gulps" droplets of extracellular fluid into tiny vesicles, formed by infoldings of the plasma membrane. In this way, the cell obtains molecules dissolved in the droplets. Because any and all solutes are taken into the cell, pinocytosis as shown here is nonspecific for the substances it transports. In many cases, as above, the parts of the plasma membrane that form vesicles are lined on their cytoplasmic side by a fuzzy layer of coat protein; the "pits" and resulting vesicles are said to be "coated."

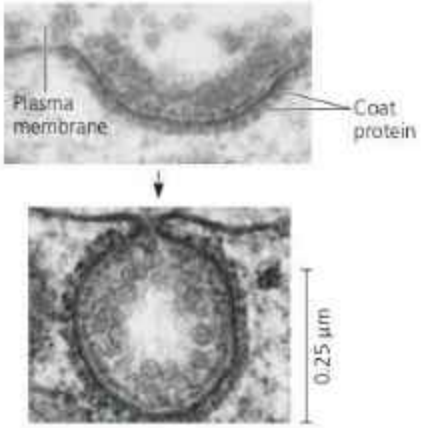


Pinocytotic vesicles forming (TEMs).

Receptor-Mediated Endocytosis



Receptor-mediated endocytosis is a specialized type of pinocytosis that enables the cell to acquire bulk quantities of specific substances, even though those substances may not be very concentrated in the extracellular fluid. Embedded in the plasma membrane are proteins with receptor sites exposed to the extracellular fluid. Specific solutes bind to the receptors. The receptor proteins then cluster in coated pits, and each coated pit forms a vesicle containing the bound molecules. The diagram shows only bound molecules (purple triangles) inside the vesicle, but other molecules from the extracellular fluid are also present. After the ingested material is liberated from the vesicle, the emptied receptors are recycled to the plasma membrane by the same vesicle (not shown).



Top: A coated pit. *Bottom*: A coated vesicle forming during receptor-mediated endocytosis (TEMs).

VISUAL SKILLS > *Use the scale bars to estimate the diameters of (a) the food vacuole that will form around the algal cell (left micrograph) and (b) the coated vesicle (lower right micrograph). (c) Which is larger, and by what factor?*

Animation: Exocytosis and Endocytosis