PHYSIOLOGY

Lec: 4

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Physiology Lecture 4 & 5

Transport of substances through cell membranes

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Lecture Objectives:

- Define diffusion and describe the factors that affect the rate of diffusion of substances across cell membranes.
- Describe facilitated diffusion.
- Compare and contrast facilitated diffusion and simple diffusion.
- Explain characteristics of carrier mediate transport, (specificity, saturation, and competition).
- Define and explain primary active transport, using the Na^{+}-K^{+} pump, and proton pump as examples of primary active transport.
- Discuss the characteristics of primary active transport.
- Define and explain the mechanism of secondary active transport.
- Explain how glucose is transported across epithelial cells in the kidney and the gut by secondary active transport.
- Define vesicular transport, transcellular transport, and their functions.
- Define osmosis and explain how osmosis takes place.
- Define osmotic pressure and explain the determinants of osmotic pressure.
- Understand how to calculate osmotic pressure.
- Describe water movement across the plasma membrane and explain the role of water channels.

Diffusion

Particles are always moving and diffuse through collisions (تصادم) of particles

- It is the random movement of substances molecules, ions, or suspended colloid particles either through membrane openings or through intermolecular spaces in the membrane, or in combination with a carrier protein.

2

- Diffusion through cell membrane is either *simple* or *facilitated*.

1

- **Simple diffusion** is passive process (no energy is required) by which particles in solution flow down a concentration gradient. Diffusion rate is determined by the (1) concentration gradient, (2) electrical gradient, and by (3) membrane permeability. It is the only form of transport that is **not carrier-mediated**.

- Lipid-soluble particles can diffuse easily, their permeability is proportional to (1) their lipid solubility and (2) the size of the particle.

cuz the C.M is made out of phospholipids

قابلية النفاذية في الـ C.M

the smaller the particle, the faster the diffussion

3

- The **selective** rapid passage of water through the membrane is achieved through *aquaporins*, which are channels used for the passage of water.

water pores

water is the fastest in diffusion cuz it has proteins for water only

(1) ex: we have a cup of water and then I Brought (احضرت) a pen and I spilled (سكبت) a drop of ink into the water. at first water will stay clear with a small blue circle, after 30 min you'll find that the water became blue, the ink droplet diffused into the whole cup and became one homogenous solution (محلول متجانس).

(1) Scientists explained that atoms or molecules are in a constant state of motion and collisions, so when they are stacked is single place, ex: ink drop, they collide with each other until they fill up the whole space

①

So, diffusion is the spreading that happens without any external power or interference and doesn't need energy, this process is called passive, and the movement of molecules is from the ↑ concentration gradient (C.G) ⟶ ↓ (C.G)

②

diffusion to cell membrane

simple

if the membrane has openings or pores the particles will enter through those pores and get to the other side and diffuse (if its radius allows it to enter)

facilitated

particles that can't enter through the pores by itself, (bcuz it is not lipid-soluble or at the right size) so, there is something helping it enter to the body (protein carriers)

(3)

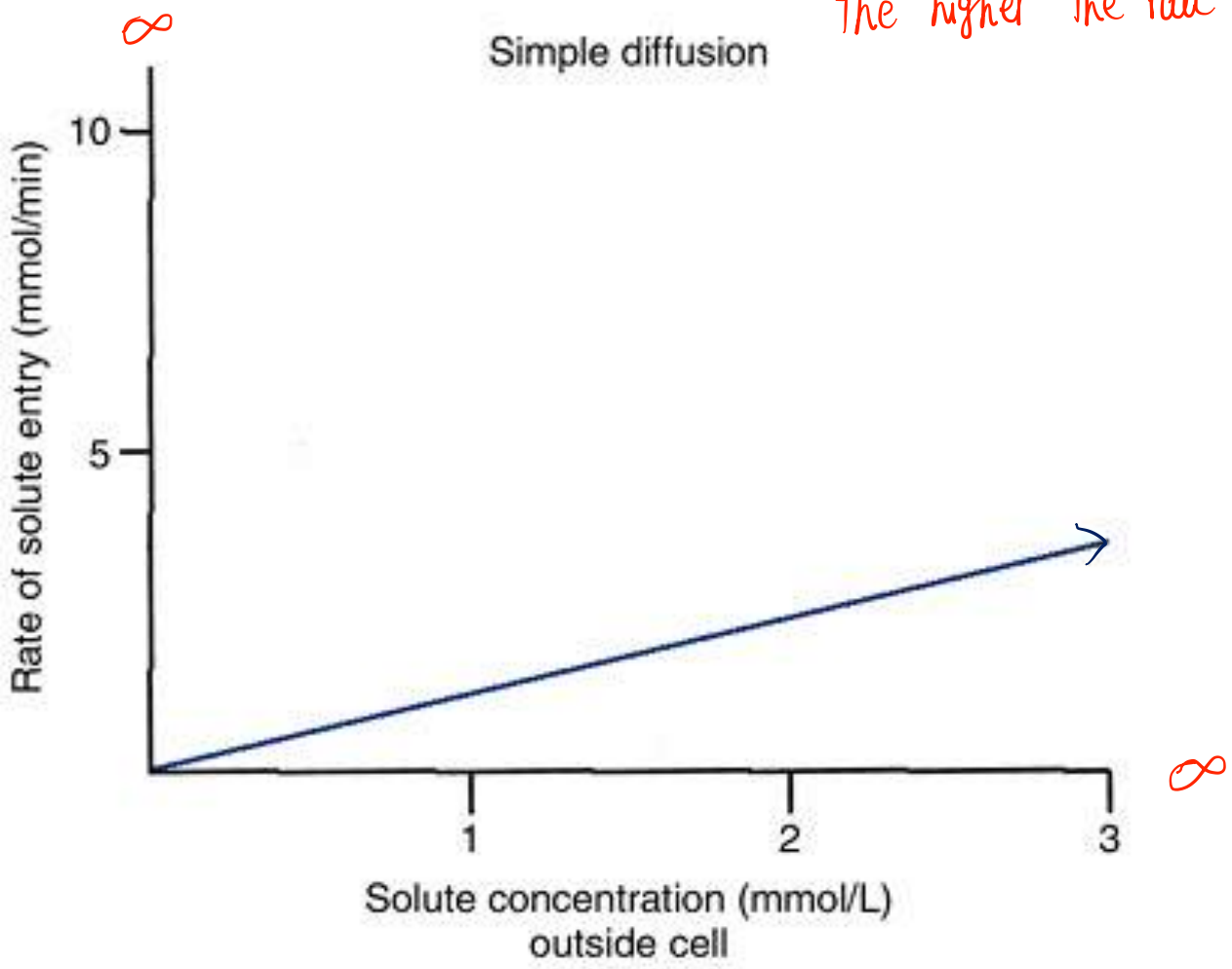
ex: of water diffusion

in kidneys, Doctors examine the C.M. of the renal tube, and they don't find any aquaporins, (this means that no water passes through) however at another times they find it full of aquaporins, after that doctors have discovered that there is a hormone (antidiuretic hormone) when this hormone gets to the cell it makes the aquaporins that are in the cytoplasm go up and connect to the cell membrane.

this hormone is essential cuz with it the water passes through and without it no water passes

Solute : مذاب
Solvent : مذيب

The higher the concentration
the higher the rate of diffusion



A graph of solute transport across a plasma membrane by simple diffusion

Diffusion (cont.)

- ***Permeability*** describes the ease with which a solute diffuses through a membrane. It depends on the characteristics of the solute and the membrane.
- The permeability increases if:
  1. Solute is lipid soluble
  2. The radius of the solute is small
  3. The membrane thickness is small

The bigger the molecule the slower it enters the C.M.
The more the thickness, the more friction happens when entering (harder to enter)

- Uncharged or nonpolar molecules such as O_2, N_2, CO_2, fatty acids, and alcohols can diffuse through lipid membrane because of their high lipid solubility.
- Water-soluble ions less than 0.8 nm in diameter diffuse through protein pore channels. Their permeability is proportional to their size, shape, and charge; as well as the number of channels through which they can diffuse.

Positive ions are easier to enter cuz of the goly cells (3rd lec) it is neg

99% of the channells are closed only in special cases

* O_2 and CO_2 molecules don't face any problems when entering or leaving the cell, they are top priority for diffusion.

O_2 spreads from outside to inside of the cell

CO_2 -- -- inside to outside -- --

* water-soluble substances have special channels that are:

1- freely open

2- opens: chemicals, voltage, mechano sensetive

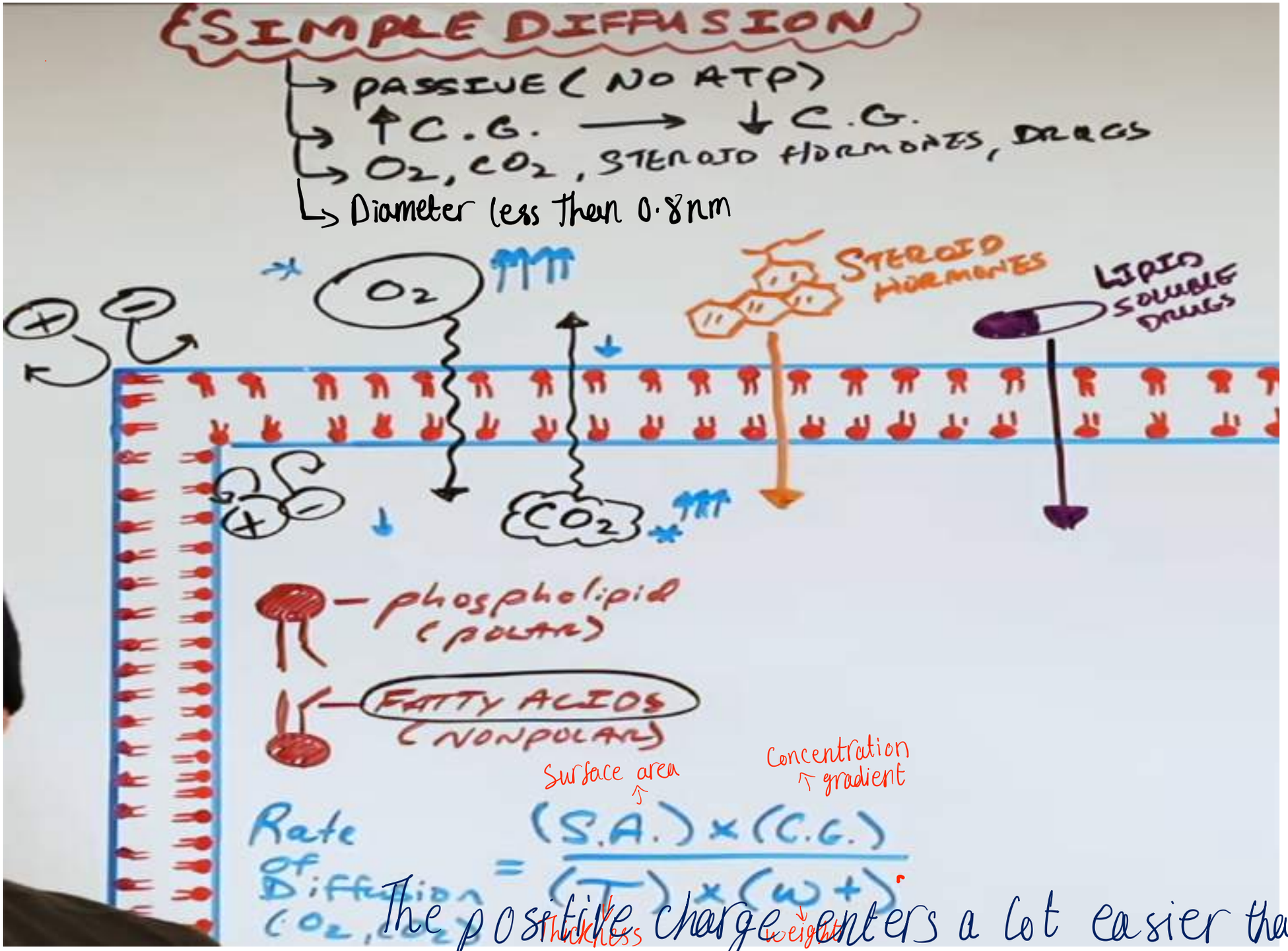
* 99% of channels are closed and open conditionally, if the channel is open, the ion with the right radius sees it as a chance to enter (like a water dam, if you opened the gate the water will start to gush out) ex: sodium is always stacked outside the cell and its diameter is less than 0.8nm, so if you opened the channel, sodium directly enters to the cell, and its entrance will be by simple diffusion (cuz we didn't need any energy or carriers)

* O_2 also enters by simple diffusion, but it enters right through the C.M. and not in a channel or a carrier

* Permeability

- → size: size of the molecule (the bigger the diameter, the less permeability becomes)
- → shape
- → channels: The more the channels The more the diffusion
- → charge: The positive charge enters a lot easier than The negative charge, This is bcuz The C.M. is negatively charged, so it attracts ⊕ ions and pushes away ⊖ ions (same as glycocalyx).

Summary of simple diffusion by ninja nerd



The positive charge enters a lot easier than

* not all aquaporins are from the same type, 90-99 % allow only water to enter, The 1-2 % allows other things such as urea (urea usually diffuse by protein carriers just like glucose)

Diffusion (cont.)

- Some lipid-insoluble molecules (such as urea) can use less selective water channels to pass.

is water

- In **facilitated diffusion** carrier protein aids passage of too large molecules or ions by binding chemically with the molecule or ion and shuttling them through the membrane in this form down an electrochemical gradient (e.g. *glucose* and *amino acids*). It does not require metabolic energy (i.e. *passive*) and is more rapid than simple diffusion.

نبسط ، نشاد ، نسهل

passive

but it is so big it can't let it enter

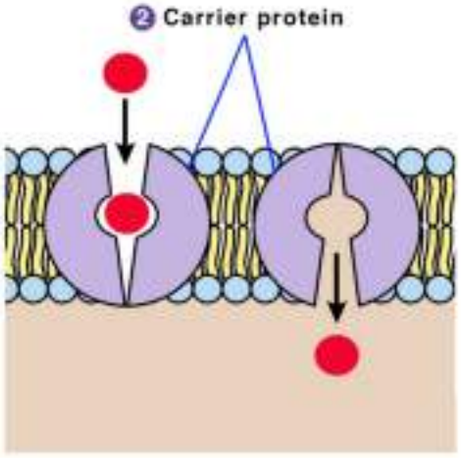
- As facilitated diffusion is carrier-mediated, therefore, it displays three important characteristics that determine the kind and amount of material that can be transferred across the membrane: ***stereospecificity***, ***saturation***, and ***competition***.

isoform نفس التركيب ولكن شكل مختلف والبروتين الي بيقل يكون خارف الشكل أو isoform جانزيم

محدد ، متخصص

- **Stereospecificity:** Each carrier protein is specialized to transport a specific substance or, at most, a few closely related chemical compounds. Example, amino acids cannot bind to glucose carriers.

Facilitated diffusion: The condition is to have a (C.G) but the molecule is larger than 0.8nm and can't go through the C.M so a carrier protein helps it to enter



* we can trick the stereospecificity and use it to transform another compound, that is closely related chemical compound

ex: Ca^{2+} is big, the protein carrier for it can be tricked and used for Mg^{2+} cuz they have the same place on the periodic table

99% of the time it can only transport one compound

Diffusion (cont.)

- **Saturation:** A limited number of carrier binding sites are available within a particular plasma membrane for a specific substance. Therefore, there is a limit to the amount of a substance a carrier can transport across the membrane in a given time. This limit is known as the **transport maximum** (***Tm*** or ***Vmax***).

velocity

This means that initially facilitated diffusion depends on the concentration gradient until all binding sites are filled (saturated); at this point, the rate of diffusion can no longer rise with increasing the concentration gradient.

Ca^{2+}, Mg^{2+}

- **Competition:** Closely related compounds may compete for a ride across the membrane on the same carrier. Example the amino acid ***glycine*** can compete with ***alanine*** for the same carrier. The rate of transport of each amino acid is less when both amino acid molecules are present than when either is present by itself.

* There is a river that the government didn't build a Bridge on it, so they had a ship (ڤيا, ڤ) to transport people from a side to another; the ship carries a total of 100 people.

10p ⟶ 10p

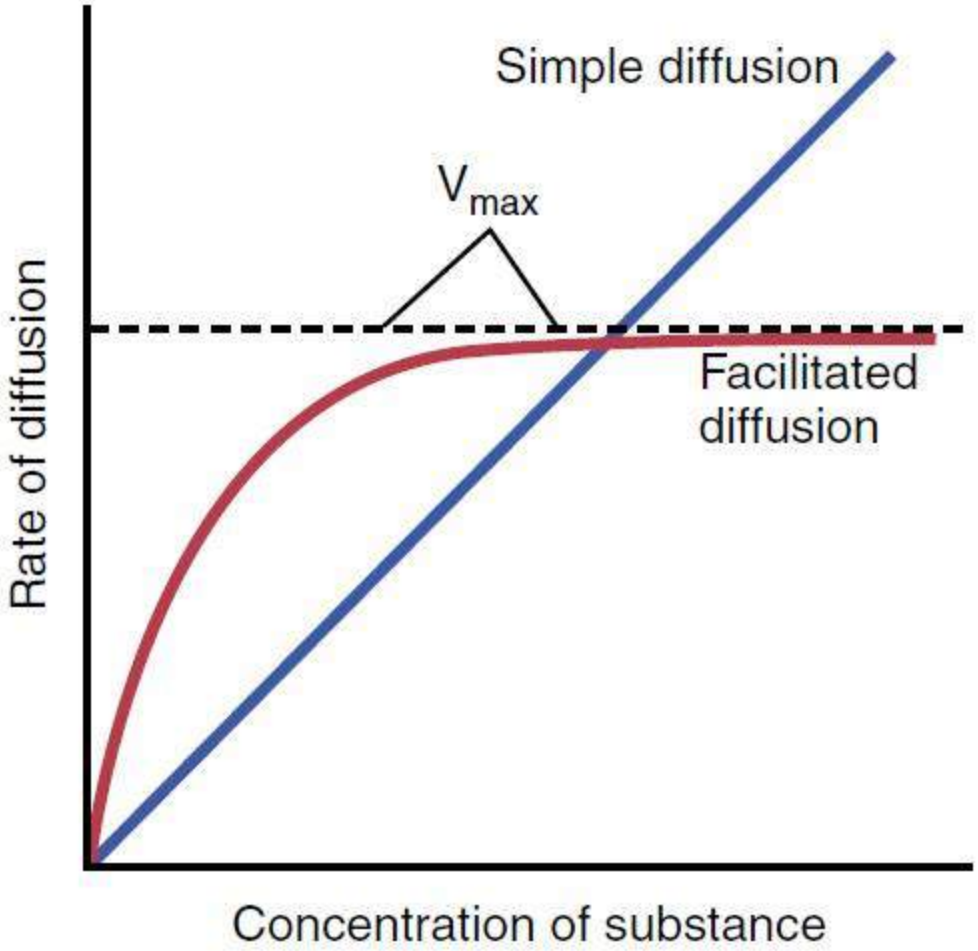
60p ⟶ 60p

100p ⟶ 100p

120p ⟶ 100p

↳ 20p

this is called transport transport maximum (v_{max})



Effect of concentration of a substance on the rate of diffusion through a membrane by simple diffusion and facilitated diffusion. This graph shows that facilitated diffusion approaches a maximum rate, called the V_{max}.

Active transport

It is the movement of molecules or ions by a cell membrane (or intracellular membranes) uphill against a concentration or electrical gradient.

Ions actively transported are Na^+, K^+, Ca^{2+}, iron, H^+, I^-, and urate ions.

→ for the thyroid gland for the secretion thyroxine

Molecules that are actively transported are different ***sugars*** and most of the ***amino acids***.

Transport depends on carrier proteins in cell membrane.

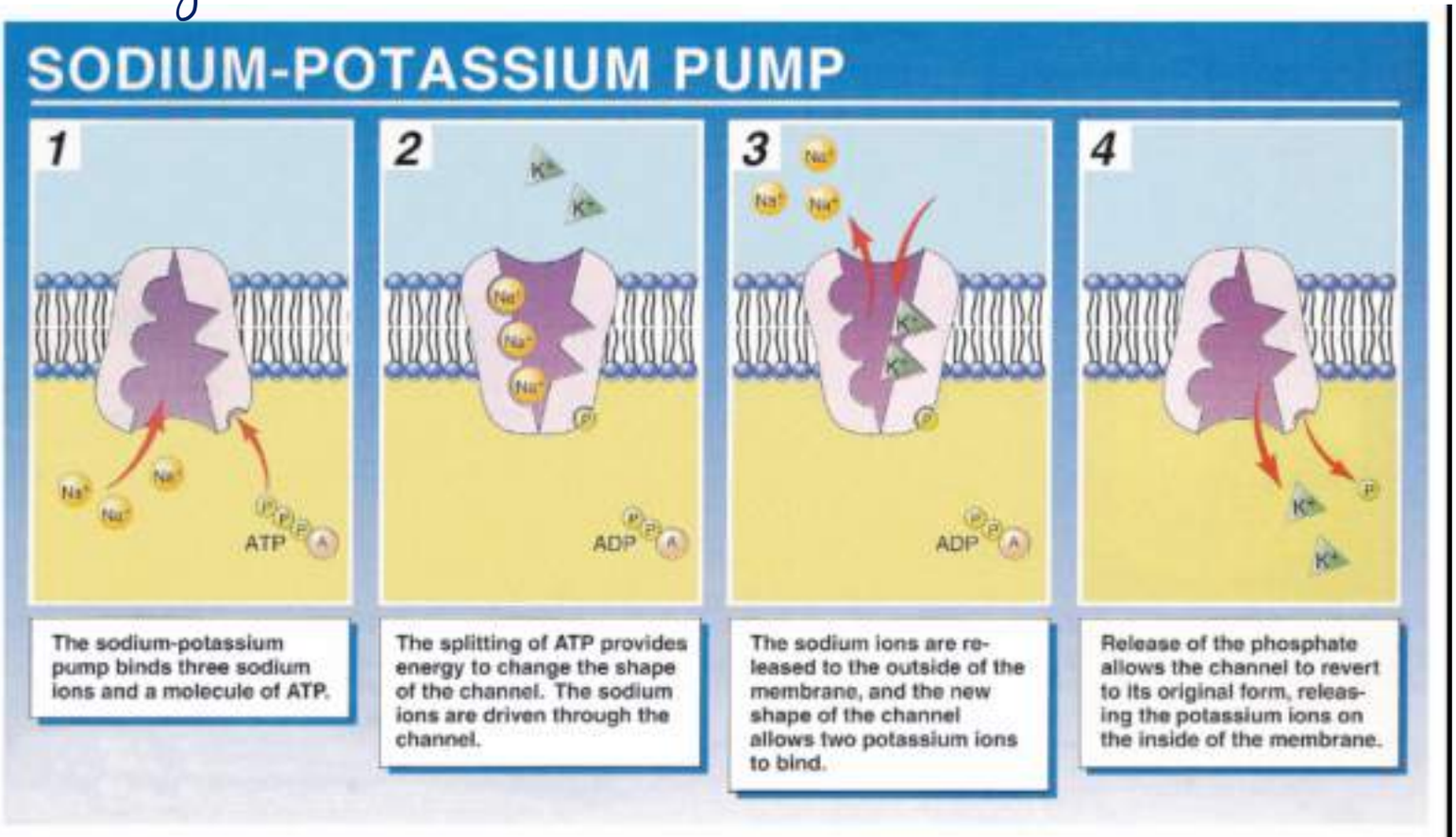
(pump)

* you ate food and it got to the intestines and is ready to be absorbed by the blood, for ex the blood glucose level was 100 and the intestines is 1000, you would say that's easy it goes down from the Int to the blood, however we will reach a point of equilibrium, 100 in the INT and a 100 in the blood, the body won't let the surplus (فائض) of glucose to the large intestines and lose it, (The large INT have 0 glucose)
(The kidney at first filters everything, good or bad, then the renal tubule filters the good stuff back to the blood stream, so this means we transported glucose from ↓(C.G) → ↑(C.G))

* Active transport needs energy to transport substances.

carrier proteins need (ATP), The protein carrier itself can work as an enzyme (ATPase) and breakdown the ATP molecule and transformit ADP and collect the energy, then use this energy to open up against its chemical gradient

ex :-



* H^+ ion :

The stomach is acidic by nature, (contains hydrochloric acid) and its pH after getting mixed with food is PH = 3, nuetral = 7

$\Delta PH = 3 - 7 = -4$

$pH = -\log [H_3O^+] = [HCl]$

$-4 = -\log [HCl]$

$4 = \log [HCl]$

$10^4 = [HCL]$

This mechanism increased the $[H^+]$ behind the C.M. 10,000 times

Iodine: any (I) that is absorbed from our food goes to the Thyroid gland no other cell can tak (I) like the (ThG) so that is from ↑(C.G) → ↓(C.G)

Types of active transport

Secondary active transport

طفيلي
(Parasital) gets energy from others

Primary active transport

gets energy on its own and works as an enzyme (ATPase)

$ATP \longrightarrow ADP + energy$