MEDICINE
KING SAUD UNIVERSITY

Physiology Team 436

Revised by
شوق الأحمري & طراد الوكيل

Tubular Reabsorption

Renal Block

Red: very important.
Green: Doctor's notes.
Pink: formulas.
Yellow: numbers.
Gray: notes and explanation.

Physiology Team 436 – Renal Block Lecture 5

For further understanding please check our "Extra Notes" file which contains extra explanation for reference books.

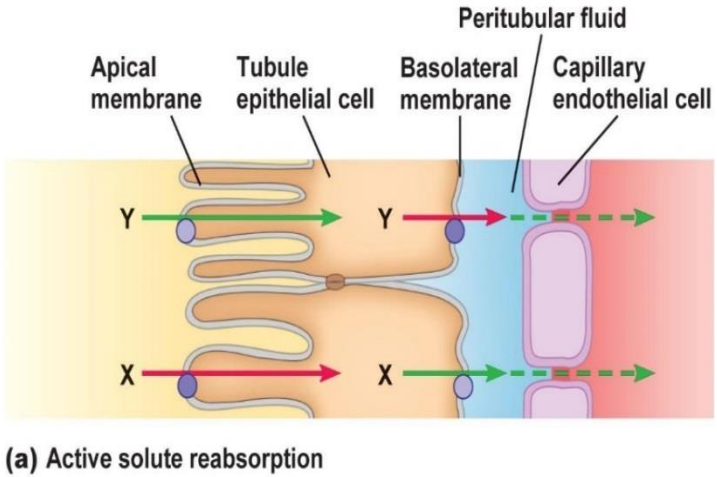
Objectives

- Define tubular reabsorption, tubular secretion, transcellular and paracellular transport.
- Identify and describe mechanisms of tubular transport
- Describe tubular reabsorption of sodium and water
- Revise tubulo-glomerular feedback and describe its physiological importance
- Identify and describe mechanism involved in Glucose reabsorption
- Study glucose titration curve in terms of renal threshold, tubular transport maximum, splay, excretion and filtration
- Identify the tubular site and describe how Amino Acids, HCO_3^-, PO_4^- and Urea are reabsorbed

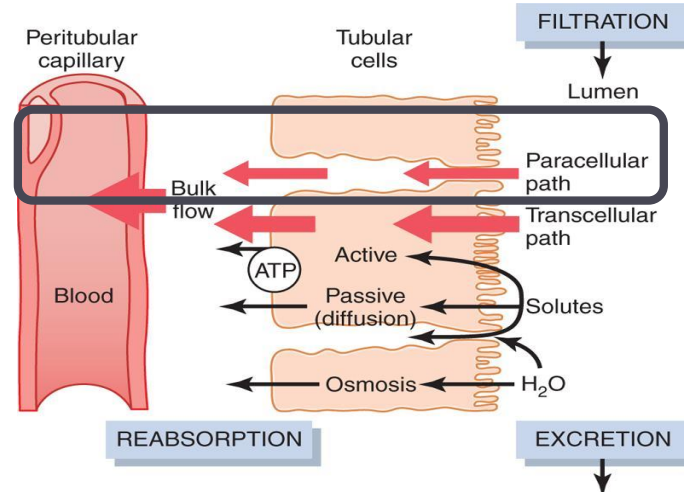
Tubular Reabsorption

- **Transported substances move through <u>three membranes</u> :**

- **Luminal** "Apical" membranes of tubule cells.
- **Basolateral** membranes of tubule cells
- **Endothelium** of peritubular capillaries
- **Ca^{2+}, Mg^{2+}, K^{+}**, and some **Na^{+}** can be reabsorbed via *paracellular pathway*. " بين الفراغات"



(a) Active solute reabsorption

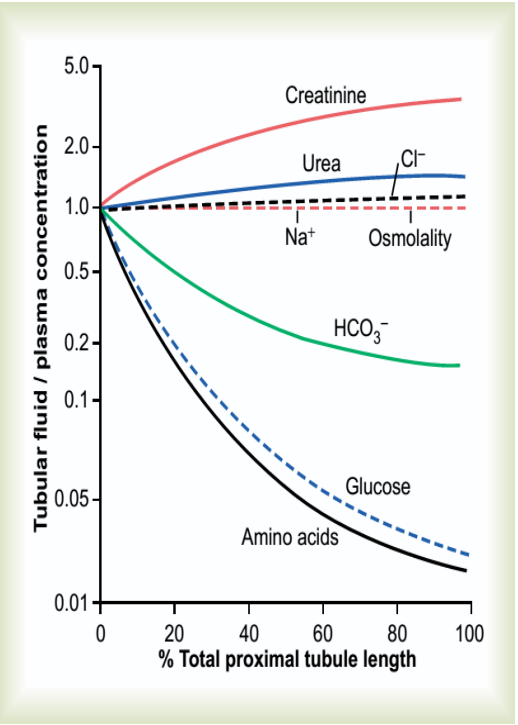


- paracellular means that the pathway is between cells.
- Transcellular means through cell.
- Paracellular:
  - Passive diffusion – Down gradient– Cross tight junction.
- Transcellular:
  Active Transportation of solutes Cross a cell.

Tubular Reabsorption

Tubular reabsorption

- All organic nutrients are reabsorbed
- Water and ion reabsorption is hormonally controlled
- Reabsorption may be an active (requiring ATP) or passive process



Examples :

- **ADH** Reabsorb water (retention of water).
- **Aldosterone** tends to promote Na^+ and water retention, and lower plasma K^+ concentration.

There is also a secondary active reabsorption which move particles by atp from another pump in glucose Example

Sodium Reabsorption: Primary Active Transport Sodium

In all areas of the nephron

- **Na+ reabsorption** is almost always by active (Needs energy) transport
- **Na+** enters the tubule cells at the luminal membrane.

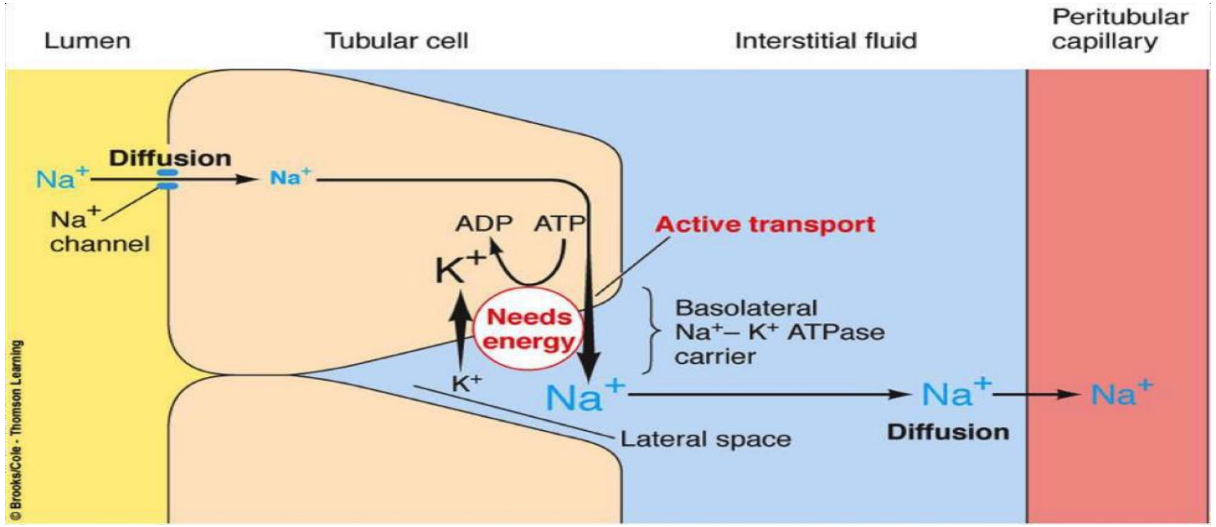
Is actively transported out of the

tubules by a Na+-K+ ATPase pump

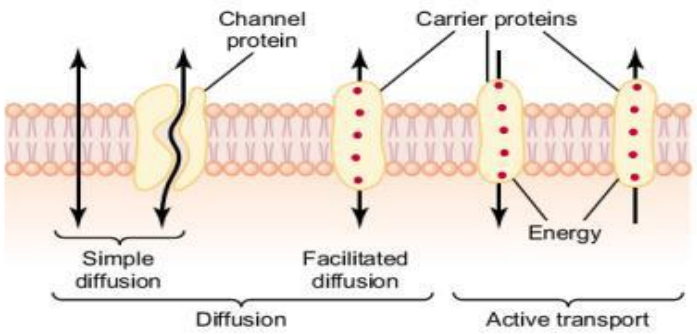
Other important solutes are linked either directly or indirectly to reabsorption of Na^+.

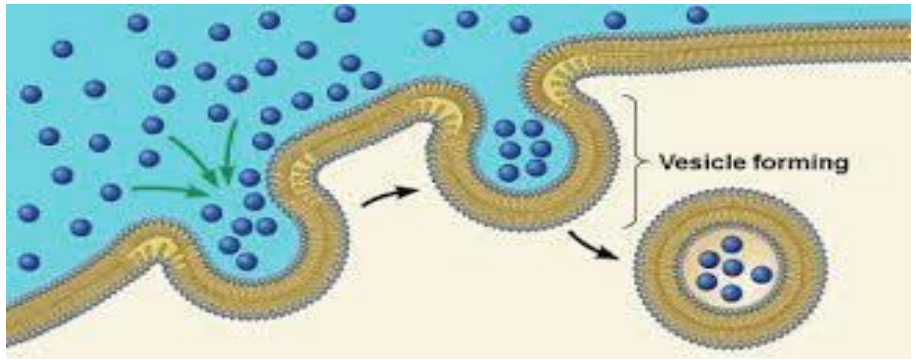
Exchanges the sodium with potassium
3 Na+ out, 2 K+ in

In the basolateral membrane of the Tubular cells



Mechanisms of Tubular Absorption & secretion





Down chemical/electrical gradient

- Passive diffusion
- Facilitated diffusion
  (Down hill = no energy, but needs a carrier)

Against chemical/electrical gradient (needs energy)

- Active transport
- Endocytosis
  (bicarbonate)

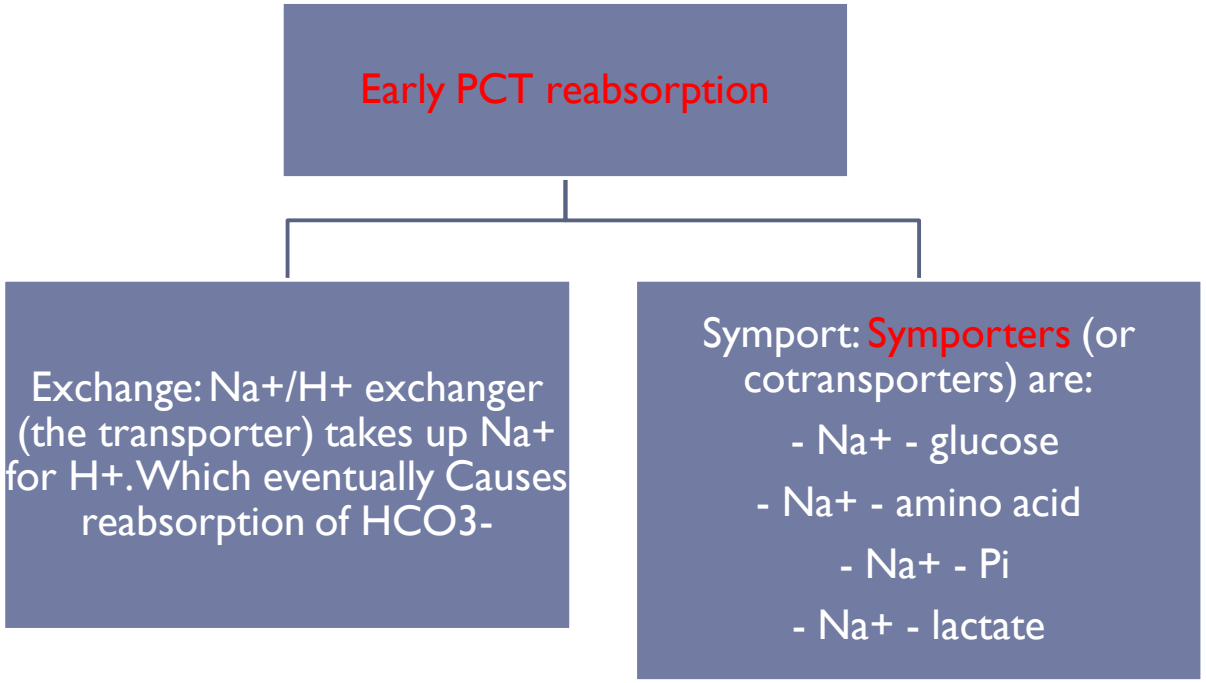
Proximal Convoluted Tubule Reabsorption (PCT):

Early stage

We will be looking at the reabsorption and secretion mechanisms of each part of the nephron

- The epithelium is *leaky*, and it's permeable to ions & water.
- **70%** of Na+, Cl-, K+ & water is absorbed passively (with/follows Na+). Sodium will pull water with it

Sodium leaves the pump through the symporters.

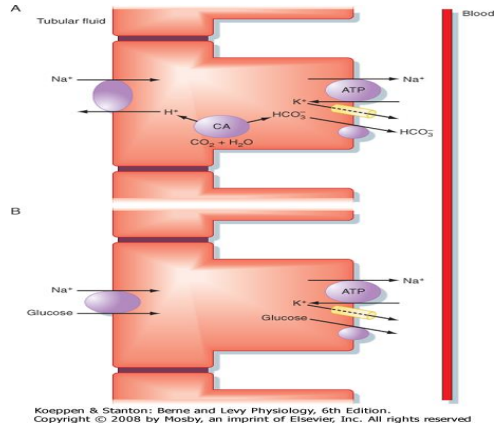


Na+ Reabsorption (transcellular):

Early PCT Na+ absorbed:

1) exchanged with H+, but HCO3- reabsorbed
2) with organic substances glucose, amino acids, lactate, Pi

} Na+/K+-ATPase important



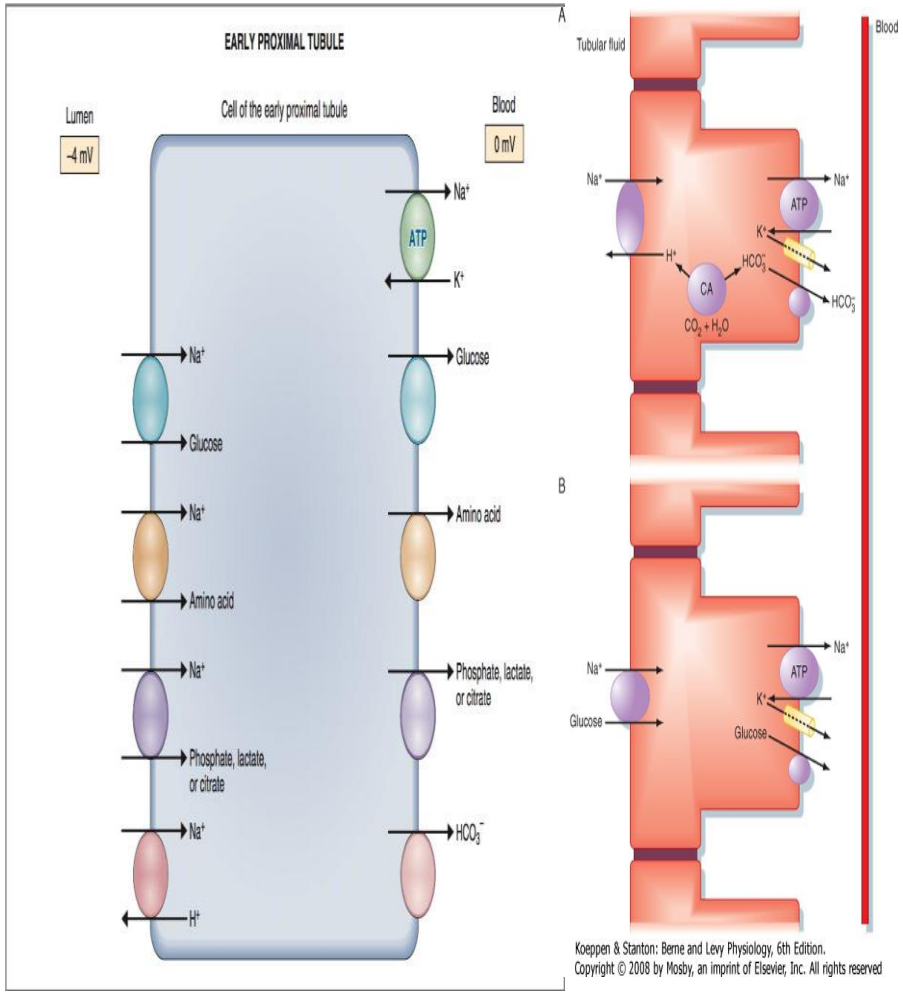
Glucose Reabsorption

- **From tubular lumen to tubular cell:** *Sodium co-transporter* (Carrier-mediated secondary active transport). Uphill transport of glucose driven by electro-chemical gradient of sodium, which is maintained by Na-K pump presents in basolateral cell membrane. (Na is downhill) So, it needs glucose and a carrier and it's an active transport

- **From tubular cell to peritubular capillary:** *Facilitated diffusion* (Carrier-mediated passive transport) (the glucose don't forget ☺)

  So, it's a passive transport but with carrier

-Carrier mediated = needs protein
-So it's an active process and needs protein



Tubular Handling of Glucose (Lecture 3: Renal Clearance)

IF plasma [glucose] = 275 mg/dl

- 275 mg/dl will be **Filtered**
- 180 mg/dl **Reabsorbed**
- 95 mg/dl **Excreted**

Tubular Transport Maximum of Glucose

- Kidney does regulate some substances by means of the $\mathbf{T_m}$ mechanism e.g sulphate and phosphate ions.
- Also subject to PTH regulation for phosphate, [PTH ↓ reabsorption].

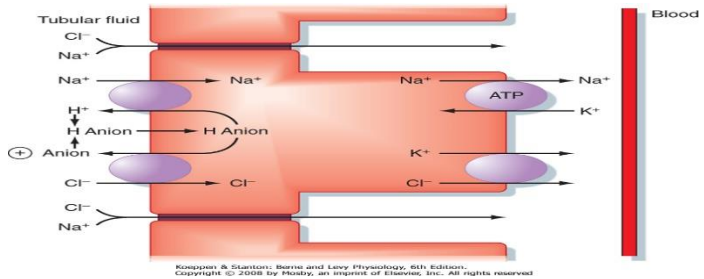
*PTH = parathyroid hormone

PCT Na+ Reabsorption: *Late stage*

Late = related to Cl-, the reason isn't important.

- **Late Proximal Convoluted Tubule:**
- **Na+ Reabsorbed mainly with Cl- ,Why ?**
- - Due to different transport mechanisms in late PCT.
- - Lack of organic molecules

Differentiae between the early and the late:
- This one is with Cl- .
- May be Transcellular or Paracellular .



2-Paracellular

- passive diffusion With Cl-
- driven by high [Cl-] in tubule
  - Conc. Of cl will favor the reabsorption into blood.
- 140mEq/L in the tubule lumen and 105 mEq/L in Interstitium only in males slides
- This conc. gradient favors diffusion of Cl- from the tubular lumen a cross the tight junction into the lateral intercellular space.

1-Transcellular → **Na+ entry using NHE & 1 or 2 Cl- - anion antiporters**

Secreted H^+ & anion combine in the tubular fluid & reenter the cell. Anions involved: OH^-, formate, oxalate, sulfate

- Cl- drags Na+ with it.

NHE = Na-H+ Exchanger , Don't forget we are talking about the Cl-

Urea Reabsorption

Normal plasma level of urea 2.5-6.5 mM/L (15-39 mg/100ml).

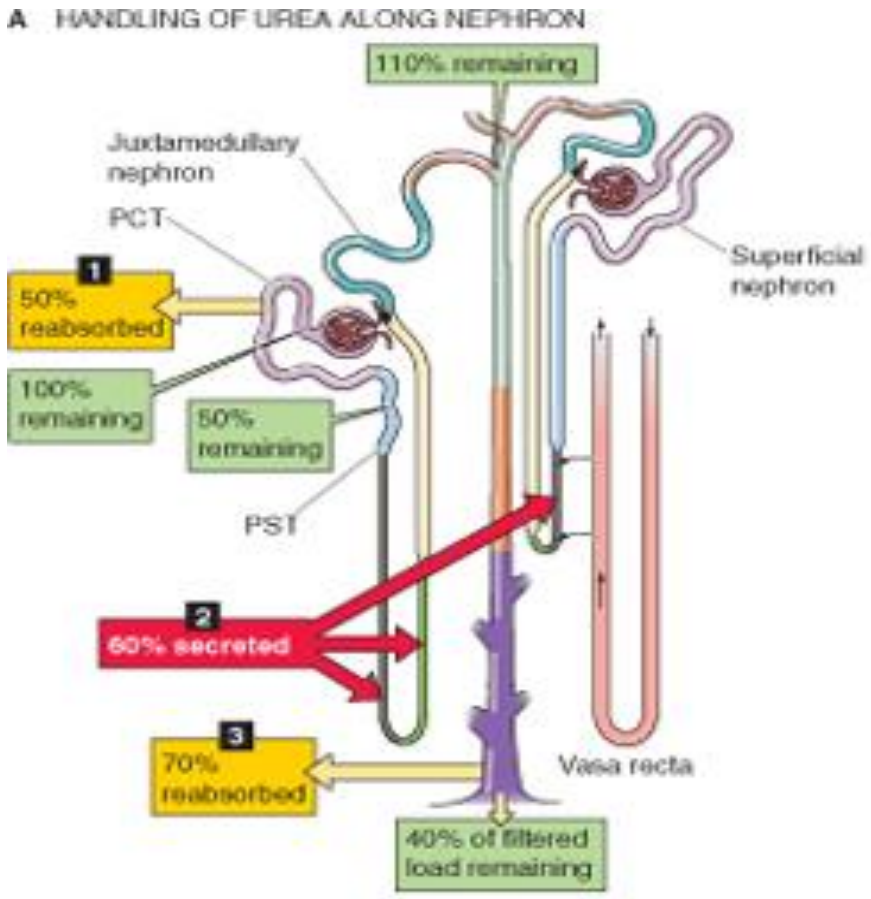
Mechanism of urea reabsorption:

- About 40-70% of filtered load of urea is reabsorbed in (areas of reabsorption):

- Second half of PCT.
- Medullary CT and CD *(ADH dependent)*.

- Due to water reabsorption in the first half of PCT, the conc. of urea is increased in the second half and urea is reabsorbed by simple diffusion *(downhill)*.

فقد الماء زاد من تركيز اليوريا مما أدى إلى سهولة انتقاله إلى الدم (passive diffusion)



 VERY IMPORTANT CD= collecting duct

It's not important

Water reabsorption

The percentages in all of them are important

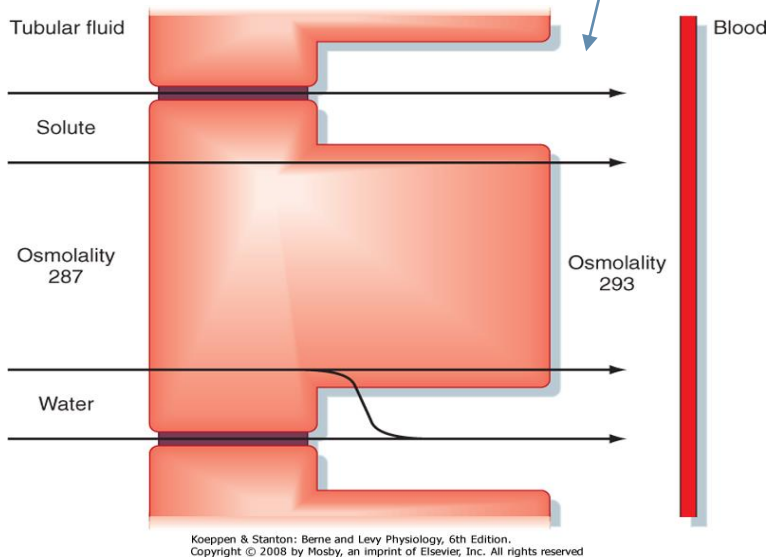
PCT cells *permeable* to water.

PCT Passively reabsorbs 67% of filtered water.

Transtubular Passive (osmosis)

due to osmotic active substances that are absorbed, e.g. *Na+, glucose, HCO3-, Cl-*

⇒ ↓ tubule osmolality.
↑ intracellular space osmolality.



Not important but read it

- Solvent drag: K+, Ca2+, carried with water & hence reabsorbed
- The accumulation of fluid and solutes within the lateral intercellular space increases hydrostatic pressure in this compartment
- The increased hydrostatic pressure forces fluid and solutes into the capillaries. Thus, water reabsorption follows solutes.

The proximal tubule reabsorption is isosmotic

Osmosis: concentration of water, from high water conc. To low water conc.

Protein Reabsorption

Peptide hormones, small proteins & amino acids are reabsorbed in **PCT**.

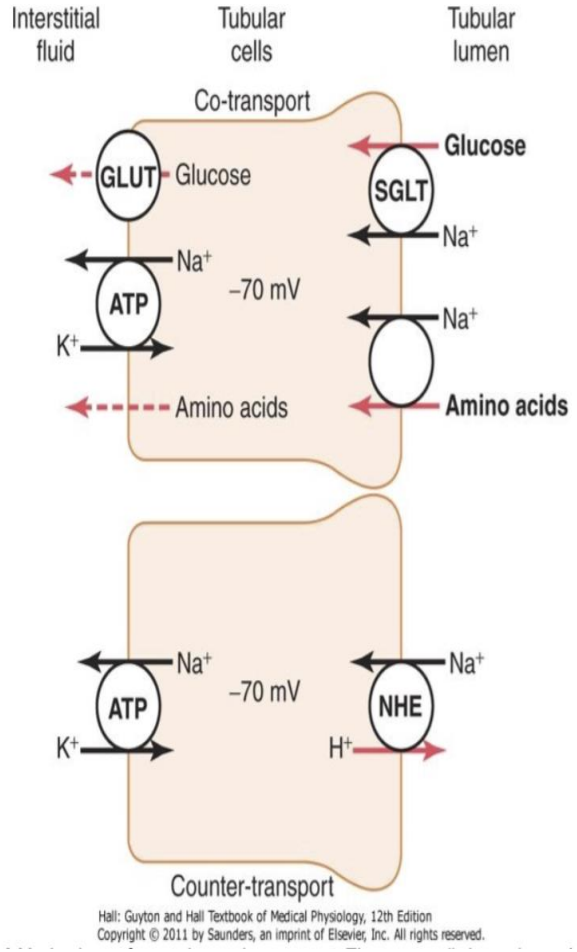
Has a maximum capacity: (T Max)
if **too much** protein is filtered → Proteinuria.

If the reabsorption exceeds it's capacity we will find protein in the urine, same with glucose. Both are abnormal.

Peptide hormones, small proteins & amino acids undergo Endocytosis into the PCT, **either** intact **or** after being partially degraded by enzymes.

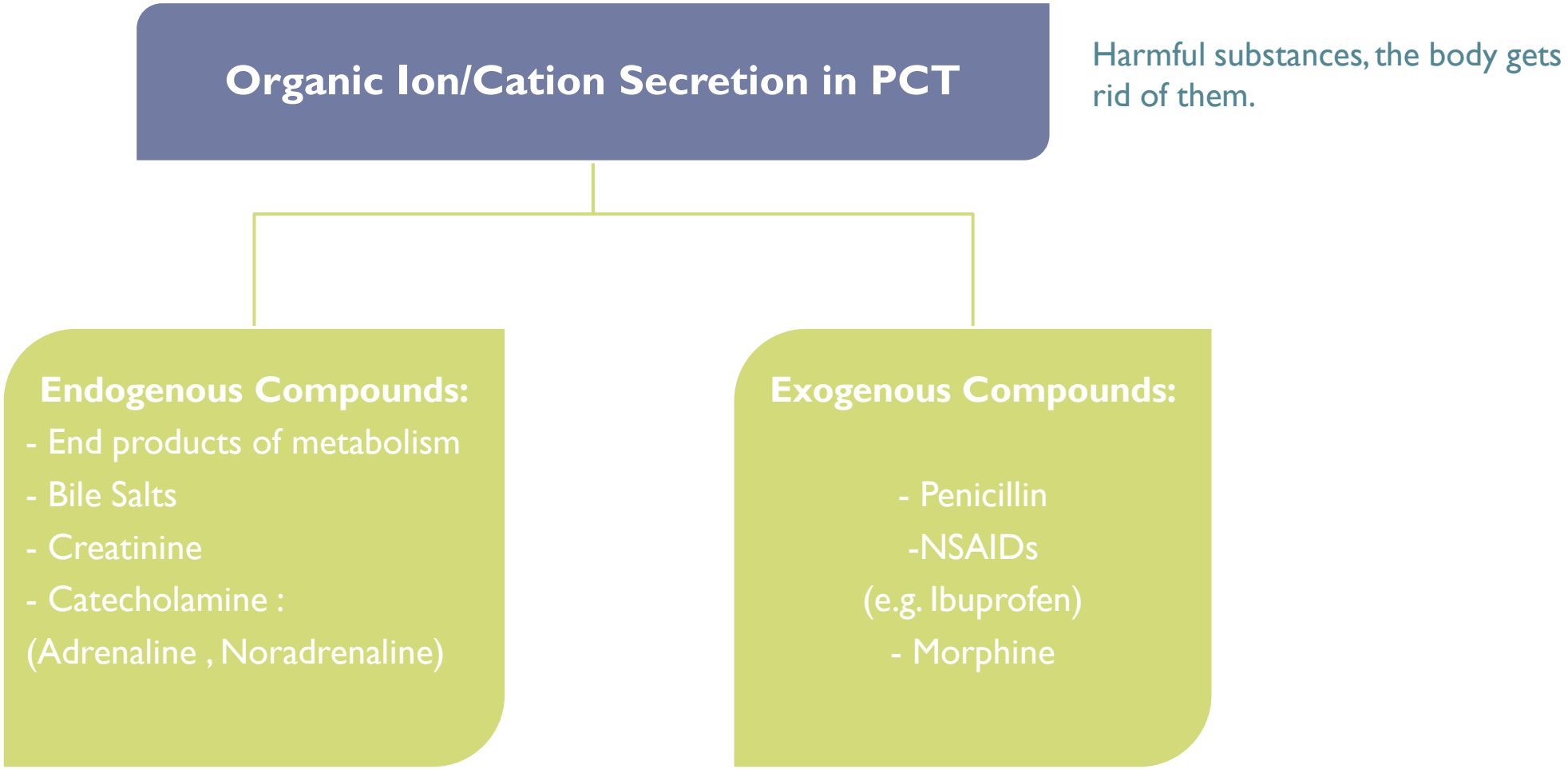
Protein enters the cell by endocytosis

Once protein is inside (engulfed) the cell, enzymes digest them into amino acids, which leave the cell to the blood.



 Endocytosis is a form of active transport in which a cell transports molecules (such as proteins) into the cell, by engulfing them in an energy-using process.

Organic Ion / Cation Secretion



Harmful substances, the body gets rid of them.

HCO_3^- Reabsorption

The renal tubules are *poorly- permeable* to HCO_3^- . **However**, it is still reabsorbed **but** in the form of CO_2 (to which the tubules are highly permeable)

This occurs through the following steps:

H^+ is formed inside the cells then secreted into the tubular fluid (through Na+ H+ pump)

→

H^+ Combines with HCO_3^- in the tubular fluid forming H_2CO_3 (unstable)

→

By activity of Carbonic Anhydrase enzyme (C.A.) in the **Tubular cells**, H_2CO_3 dissociates into CO_2 & H_2O

↓

CO_2 Diffuses into the cells Where it combines with H_2O (By activity of **intracellular** C.A), Forming H_2CO_3 which dissociates into HCO_3^- & H^+

→

HCO_3^- passively diffuses into the interstitial fluid (then to the blood) while H^+ is secreted into the tubular fluid to help more reabsorption of HCO_3^-

It gets in through the reaction , never gets in directly

H+ out in exchange of Na+

Tubules are highly preamble to CO2 > H+ ions are formed inside the cells >secreted in the tubular fluid through NHE pump > H+ combines with CO2 to form H2CO3 in the tubular fluid > CA disassociate H2CO3 into CO2 and H+ > CO2 diffuse into the cell where combines with water and it keep repeating > CO2 gets out the cell by passive diffusing into the interstitial fluid (blood) H+ is secreted through the pump tubular lumen.

15 Bicarbonate is the only molecule doesn't get reabsorbed as it self must be converted

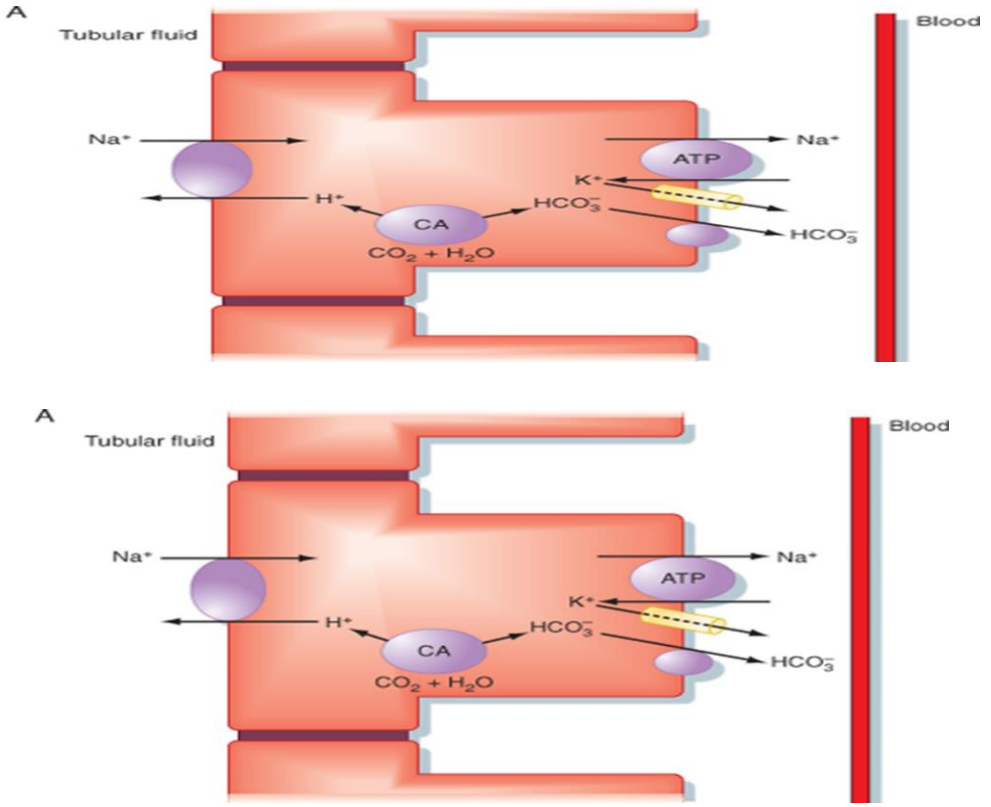
HCO_3^- Reabsorption, Cont..

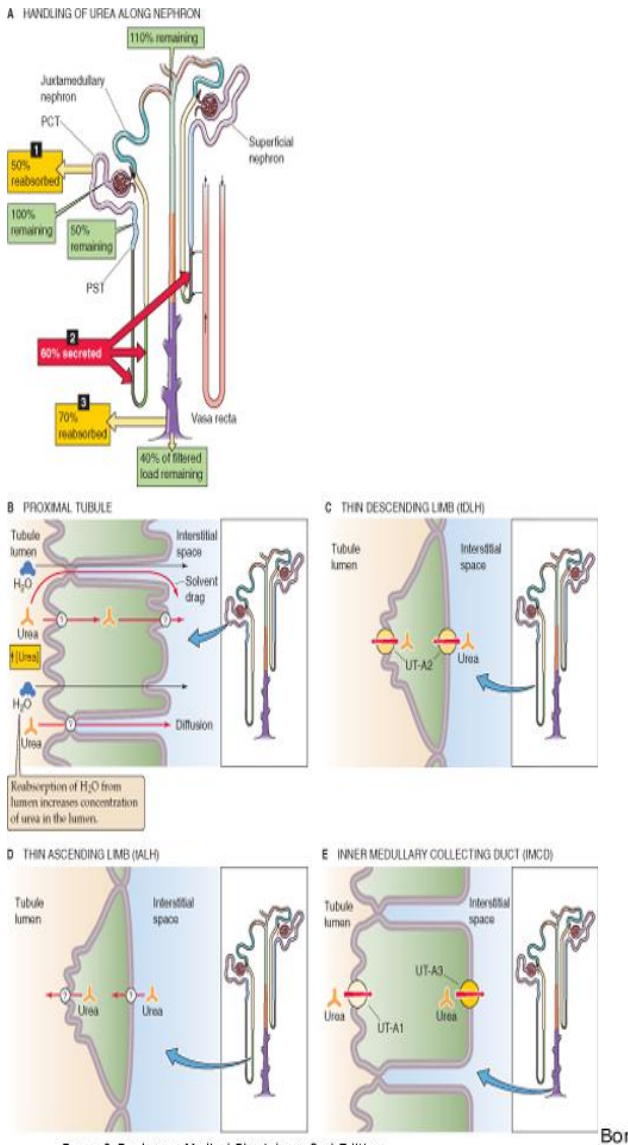
Factors Affecting HCO_3^- Reabsorption:

- Arterial P_{CO2}
- Plasma $[K^+]$
- Plasma $[Cl^-]$
- Plasma Aldosterone

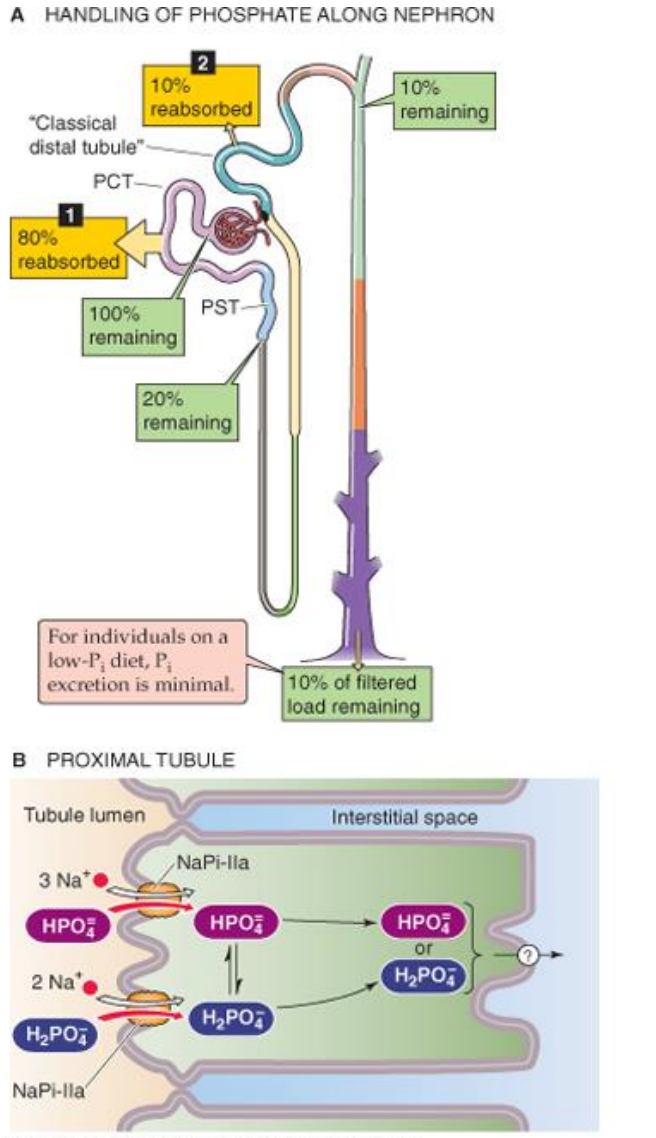
- Low levels of Pco2 = decreased the levels of reabsorption.Vice versa

- High Pco2 = investigate the lungs

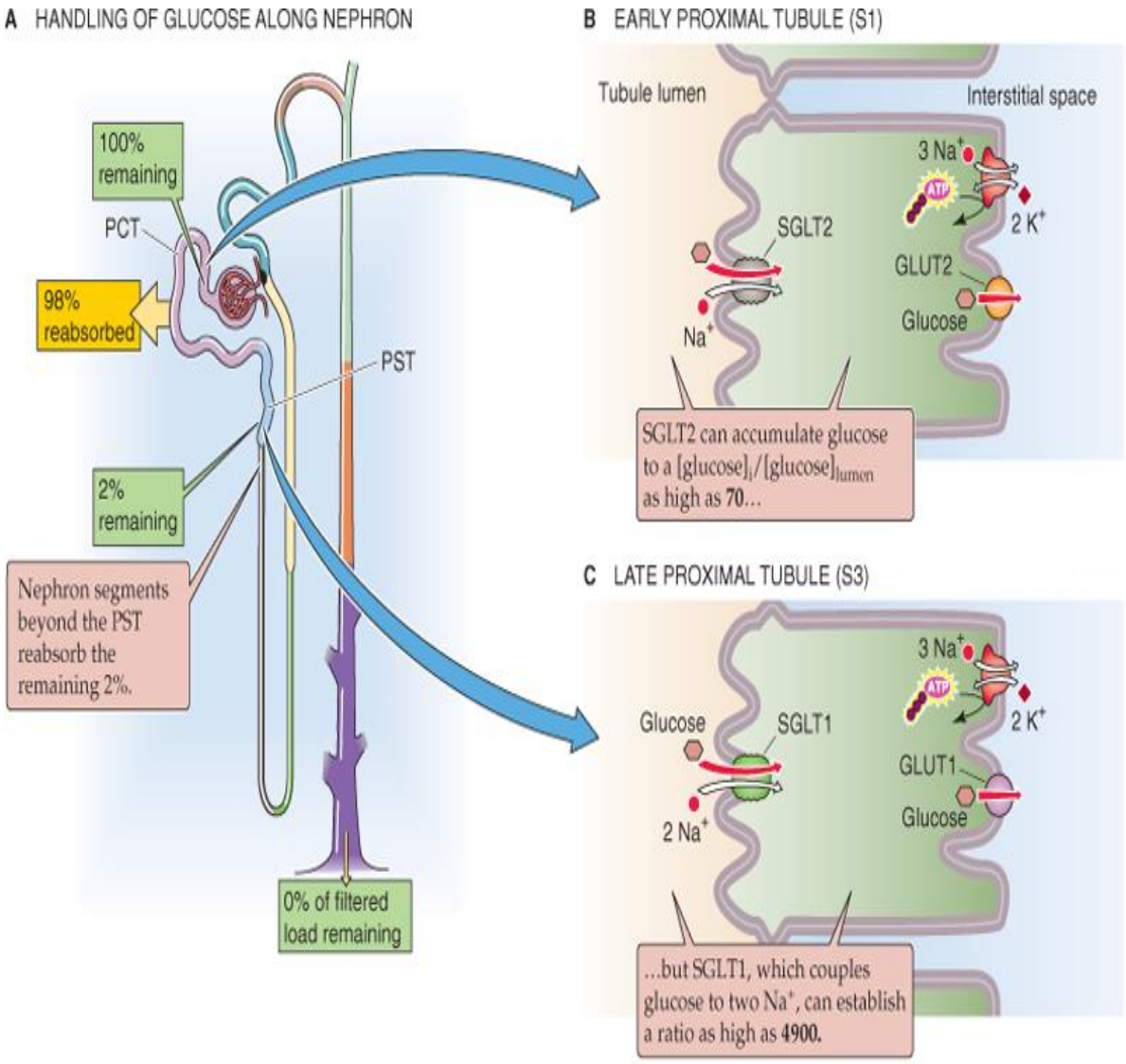




Boron & Boulpaep: Medical Physiology, 2nd Edition.
Copyright © 2009 by Saunders, an imprint of Elsevier, Inc. All rights reserved.



Boron & Boulpaep: Medical Physiology, 2nd Edition.
Copyright © 2009 by Saunders, an imprint of Elsevier, Inc. All rights reserved.



Boron & Boulpaep: Medical Physiology, 2nd Edition.
Copyright © 2009 by Saunders, an imprint of Elsevier, Inc. All rights reserved.

Thank you!

اعمل لترسم بسمة، اعمل لتمسح دمعة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

The Physiology 436 Team:

Female Members:
Allulu Alsulayhim
Ghada Alhadlaq

Male Members:
Ali Alsubaie
Abdullah Abuamara

Team Leaders:
Qaiss Almuhaideb
Lulwah Alshiha

Contact us:

Physiology436@gmail.com

@Physiology436

Link to Editing File

References:

- Girls' and boys' slides.
- 435 Team.
- Guyton and Hall Textbook of Medical Physiology (13th Edition).
- Linda (5th Edition).

Special thanks to Team435's Leaders: Meshal Alhazmy & Khawla Alammari and members!