MED439
KING SAUD UNIVERSITY

Physiology Team 439

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PHYSIOLOGY

BUFFER SYSTEM

Black: in male AND female slides
Red : important
Pink: in female slides only
Blue: in male slides only
Green: Notes
Gray: extra information

Editing file

Buffer

Definition

solution (a mixture of a weak acid and a weak base that are in equilibrium) that resists changes in pH upon addition of small amount of acids and bases.

To be more accurate, its either made of:

1 ▪ A weak acid and its conjugated base ($H2CO3$ & $NaHCO3^-$).

2 ▪ A weak base and its conjugated acid ($NH3$ & $NH4^+$).

How does a buffer do its job ?

Neutralizes small additions of bases/acids —> pH remains constant. (we use buffers in laboratory tests and analysis)

If I add small amount of an acid or avbase, BUFFER solution will resist the decrease/increase in pH

Without buffer if i add acid into a solution —> pH will decrease.

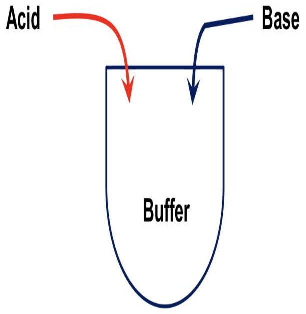
Without buffer if i add base into a solution —> pH will increase.

Comparison of changes with and without buffer:

Pure water (pH=7) + base =

With buffer solution : 7-7.5

Without buffer solution: 7-9



For better understanding check slide 4

Chemical Buffer Systems in the Body

There are 3 chemical buffers in the body:

- The Bicarbonate buffer system —> (powerful extracellularly).
- The phosphate buffer system —> (powerful intracellularly) and it's very good in tubular filtration (will be discussed later)
- Proteins —> (powerful intracellularly).

They are the 1st line of defence against changes in pH i.e. [H+], act within seconds.

Some are more powerful extracellularly and others are more powerful intracellularly. It depends on where is the most of their conc. in other word; if it's more abundant extracellularly it will become more powerful extracellularly.

-Buffer's power Depends on relative amount of Acid and Base in a Buffer solution.
-It is maximum when both are in equal amounts.
-Absolute concentration of Buffers in body fluids is also important.
-If the pH of medium is near pK of buffer system it becomes more effective.

The Bicarbonate Buffer System

Bicarbonate is the main ECF buffer system cuz it’s the highest anion in ECF with chloride (as we discussed before),

which is Composed of:

- A weak acid (H2CO3).
- Its conjugated base (NaHCO3).

Bicarbonate is the most abundant anion in ECF so it will bind to most abundant cation in ECF which is Na+ and forming = NaHCO3 which is **Conjugated base**

$$CO_2 + H_2O \xrightleftharpoons{CA} H_2CO_3 \rightleftharpoons H^+ + \boxed{HCO_3^-}$$

$$\boxed{NaHCO3} \rightleftharpoons Na+ + HCO_3^-$$

it secreted by many reactions not only from carbonic acid. E.g: Kidney, metabolism of amino acids

CA: Carbonic anhydrase; it accelerate the binding of H2O with CO2 cuz it’s very slow.

1

H2CO3 forms in the body by the reaction of CO2 &H2O

$$CO_2 + H_2O \xrightleftharpoons{CA} H_2CO_3$$

2

H2CO3 ionizes weakly to form small amounts of H+ & HCO3-

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

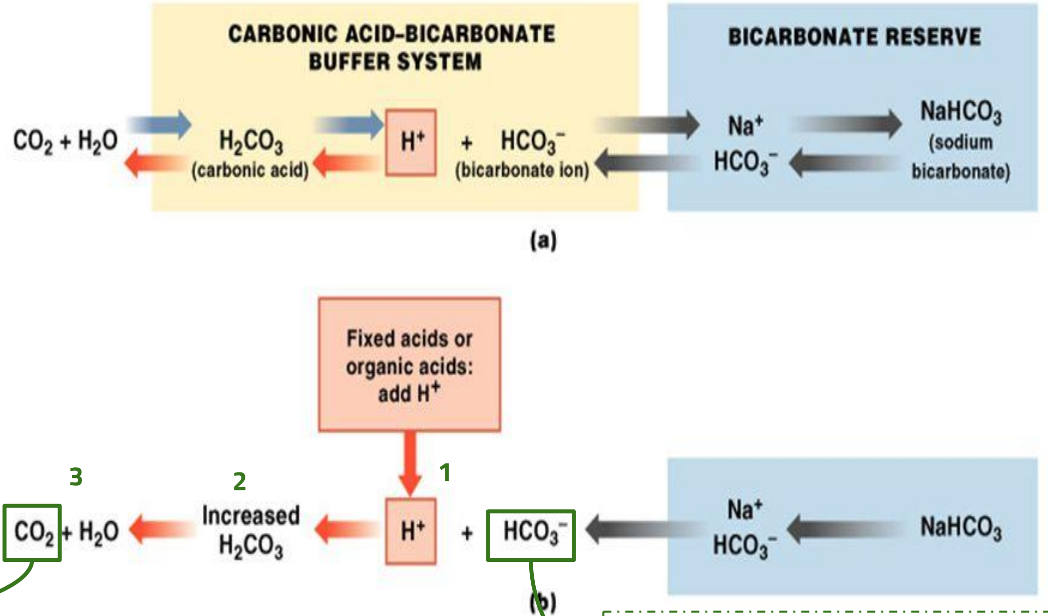
3

The second component is NaHCO3 which dissociates to form Na+ & HCO3-

$$NaHCO3 \rightleftharpoons Na+ + HCO_3^-$$

Putting it all together :

In Homeostatic condition



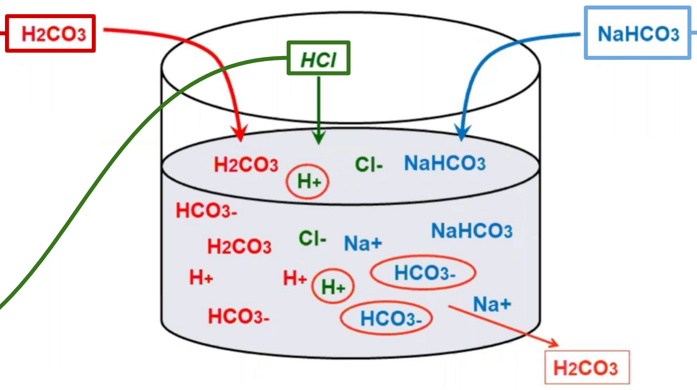
Can be exhaled through the lung

بعد ما ارتبط معظمه مع H فبيقل تركيزه،
فلازم تعويض من NaHCO3
يتفكك ويعطينا HCO3 + Na

Explanation of how does a buffer do its job in different solution:

• Bicarbonate buffer solution (if we add Strong acid)

Weak acid:
Will not dissociate completely
=produce (HCO3 + H) + H2CO3



Conjugated base:
Will not dissociate completely
=produce (HCO3 + Na) + NaHCO3

Strong acid added into solution:
Will dissociate completely
so it will release all the Hydrogen ions rapidly
= Produce (Cl + H)

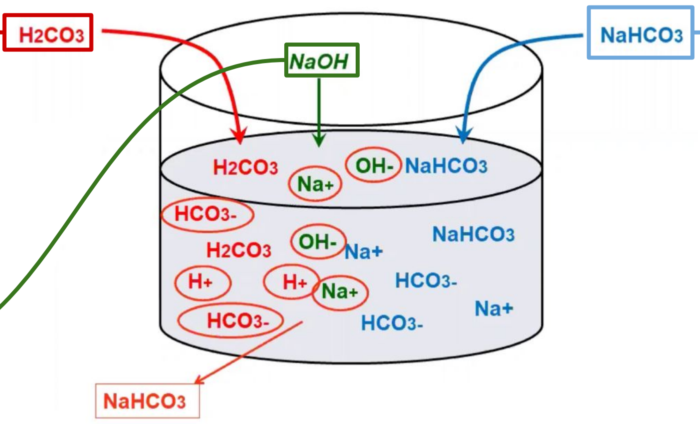
H+ is an Acid, pH will **drop** because high conc. Of Hydrogen

Now buffer solution will do its job:
It will bind hydrogen to HCO3- "base of the solution"
H+HCO3- = H2CO3! Carbonic acid again, weak acid again
What's the benefit of formation weak acid?
1- free H is more danger than hidden/bind hydrogen
2-weak acid has slower dissociation than strong acid
فبدل ماينخفض الpH من ٧.٤ الى ٧ تخليه يوصل ٧.٣٥ يعني تقلل الحدرة، مايهم
HCO3- طالعة من acid or base لأن مايفرق اصلاً بينهم

The strong acid is converted into a weak acid

• Bicarbonate buffer solution (if we add Strong base)

Weak acid:
Will not dissociate completely
=produce (HCO3 + H) + H2CO3



Conjugated base:
Will not dissociate completely
=produce (HCO3 + Na) + NaHCO3

Strong base added into solution:
Will dissociate completely
so it will release all the OH ions rapidly
= Produce (OH + Na)

OH is a Base, pH will **Increase sharply** because high conc. Of OH

Now buffer solution will do its job:
(Na will bind to HCO3- = NaHCO3 (weak base!
What's the benefit of formation weak base?
1.because it has slower dissociation than the strong one
2.Also OH will bind to Hydrogen ion = H2O

The strong base is converted into a weak base

Has the body now completely got rid of all excess acid (H+) or excess base (OH)?

No they only <u>got hidden</u>, this a limitation of free ions until the lung and the kidney do their job.

From female slides

The Henderson-Hasselbalch Equation (HHE)

Definition

HHE is an equation that enables the calculation of pH of a solution.

$$pH = pK + \log \frac{HCO_3^- \text{ conjugated base}}{0.03 \times PC_2 \text{ weak acid}}$$

- K = dissociation constant.
- pK = 6.1
- solubility of CO_2=0.03.

How was HHE derived?

1

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

H2CO3 and its dissociated ions are always in equilibrium → the products of the reaction on one side of the equation are proportional to the product on the other side.

(1) $[H_2CO_3] \propto [H^+] \times [HCO_3^-]$

- Since H2CO3 is a weak acid, it will not dissociate completely and the concentration of its products will depend on its dissociation constant (K)

(2) $K \times [H_2CO_3] = [H^+] \times [HCO_3^-]$

2

Based on the (1) and (2) equations, [H+] can be expressed as follows:

$$[H^+] = K \times \frac{[H_2CO_3]}{[HCO_3^-]}$$

↑ $[H^+]$ →↑ $[H_2CO_3]$ Directly proportional

↑ $[H^+]$ → ↓ $[HCO_3^-]$ inversely proportional

3

Because H_2CO_3 can rapidly dissociate into CO_2 and H_2O. And since CO_2 is much easier to measure it can replace H_2CO_3in the equation:

$$[H^+] = K \times \frac{[CO_2]}{[HCO_3]}$$

This is Henderson's equation (1908)

It means that:
↑ [CO2] →↑ [H+]
↑ [HCO3-] → ↓ [H+]

4

In 1909, Sorensen created the pH scale to express [H+]:

$$pH = -\log[H^+]$$

5

In 1916, Hasselbalch decided to merge Henderson's equation with Sorensen's pH scale

$$[H^+] = K \times \frac{[CO_2]}{[HCO_3^-]} \longrightarrow -\log[H^+] = -\log K \times \frac{[CO_2]}{[HCO_3^-]}$$

$$-\log[H^+] = -\log K \times \frac{[CO_2]}{[HCO_3^-]} \longrightarrow \boxed{pH = pK + \log \frac{[HCO_3^-]}{[CO_2]}}$$

This is Henderson-Hasselbach equation

6

Since it is much easier to measure PCO_2 rather than dissolved $[CO_2]$ and because dissolved CO_2 is proportional to PCO_2 multiplied by the solubility of CO_2 (0.03 mmol/mmHg) → $[CO_2]$ was replaced by PCO_2 X 0.03

$$pH = pK + \log \frac{[HCO_3^-]}{0.03 \times PCO_2}$$

$$pH \propto \frac{HCO3- \text{ Regulated by kidney}}{PCO2 \text{ Regulated by Lung}}$$

Each element of the buffer system is regulated

It is not only the amount of base and acid that is important but the ratio between them must remain constant.

The importance of this equation (HHE):
1- to calculate the pH using the concentrations of bicarbonate and CO2
2- pH and HCO_3^- Directly proportional
3- pH and PCO_2 inversely Proportional

The Bicarbonate Buffer System

Why is it the most important buffer system in the ECF?

1 ▪The CO_2 component of the buffer is regulated by the lungs

2 ▪ The HCO_3^-component of the buffer is regulated by the kidneys

Ratio of $\frac{\textbf{HCO3}}{\textbf{PCO2}}$ Is= 20:1 (important) it means we have HCO3 more than H3CO3

Buffer	Composed of	Importance	Pk value
Bicarbonate	HCO_3 & H_2CO_2	In ECF / plasma	6.1
Phosphate	HPO_4^{-2} (Hydrogen phosphate) & $H_2PO_4^-$ (dihydrogen phosphate)	In ICF / renal tubular fluid conc. in ECF is only 8 % of bicarbonate	6.8
Ammonia	NH_3 & NH_4^+	In Urine	9
Proteins (Amphoteric) Proteins will bind with hydrogen , How? Proteins have COOH (carboxyl group, -ve charge) and amino group (+ve charge) So the negative (COOH) is the highest and it makes protein bind with hydrogens	Prot & H Prot most proteins in our body are negative	In ICF	-
Hemoglobin (due to protein's -ve charge)	Hb & HHb The most important protein in RBCs It's a negative protein so it binds to hydrogen until lungs and kidney work	In ICF	-

NOTE: A pKa of 6.8 Makes Phosphate a Good Buffer in ECF however, its plasma conc. is low (about 1 mmol/L) unlike HCO_3^- which is 24 mmol/L

Summary of Body's Buffering Systems

- Buffer systems do not work independently in body fluids but actually work together
- Buffers do not reverse the pH change, they only limit it
- A change in the balance in one buffer system, changes the balance of the other systems
- Buffer dont correct changes in [H^+] or [HCO_3^-] they only limit the effect of change on body pH until their concentration is properly adjusted by either the lungs or the kidney

From boys slides

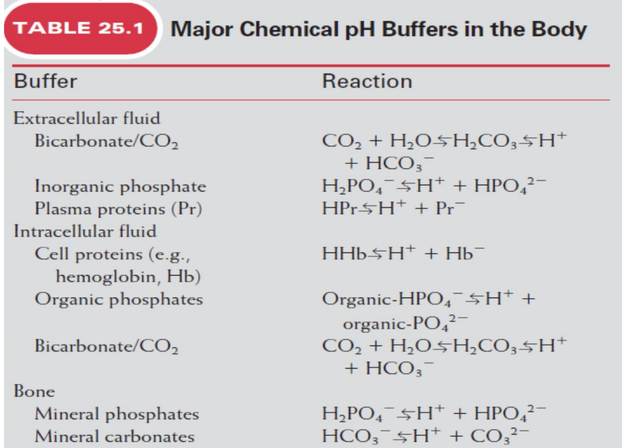


TABLE 25.1 Major Chemical pH Buffers in the Body

Buffer	Reaction
Extracellular fluid	
Bicarbonate/CO_2	$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
Inorganic phosphate	$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$
Plasma proteins (Pr)	$HPr \rightleftharpoons H^+ + Pr^-$
Intracellular fluid	
Cell proteins (e.g., hemoglobin, Hb)	$HHb \rightleftharpoons H^+ + Hb^-$
Organic phosphates	$\text{Organic-}HPO_4^- \rightleftharpoons H^+ + \text{organic-}PO_4^{2-}$
Bicarbonate/CO_2	$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
Bone	
Mineral phosphates	$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$
Mineral carbonates	$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$

From female slides

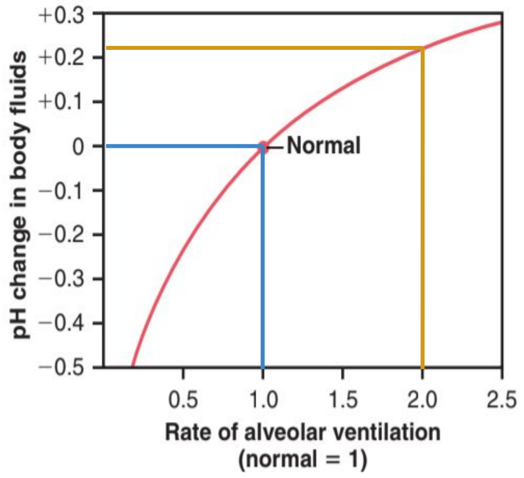
Respiratory Regulation of acid-base

- 2nd line of defence against acid-base disturbances in the body.
- Respiratory system regulate acid - base by modulating CO_2 excretion
- works within minutes
- Normally, PCO_2 = 40 mmHg (35-45 mmHg) you have to memorize it.

Acidosis: Increase [H^+]↑ → Hyperventilation ↑ → Decrease PCO_2↓ → Increase pH↑ (more alkalosis)

Alkalosis: Decrease [H^+] ↓ → Hypoventilation ↓ → Increase PCO_2↑ → Decrease pH ↓ (more Acidosis)

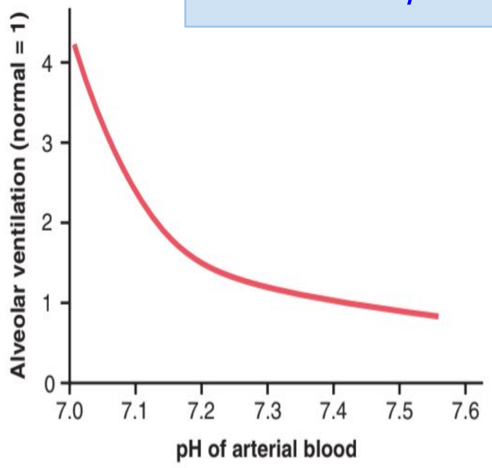
From boys slides



doubling(Twice normal) the ventilation rate raises the pH of the extracellular fluid from 7.4 → 7.63 (+0.23)

Respiratory Regulation of Acid-Base Balance

When the alveolar ventilation increase the pH of body fluids <u>increase</u>



Effect of blood pH on rate of alveolar ventilation

When the alveolar ventilation increase the pH of body fluids <u>Decrease</u>

Renal Regulation of acid-base

1 3nd line of defence.
Most powerful system that works within hours to days (slowest)

2 It regulates by excreting either an acidic or basic urine

3 The kidney secretes acidic or alkaline urine based on acid-base status

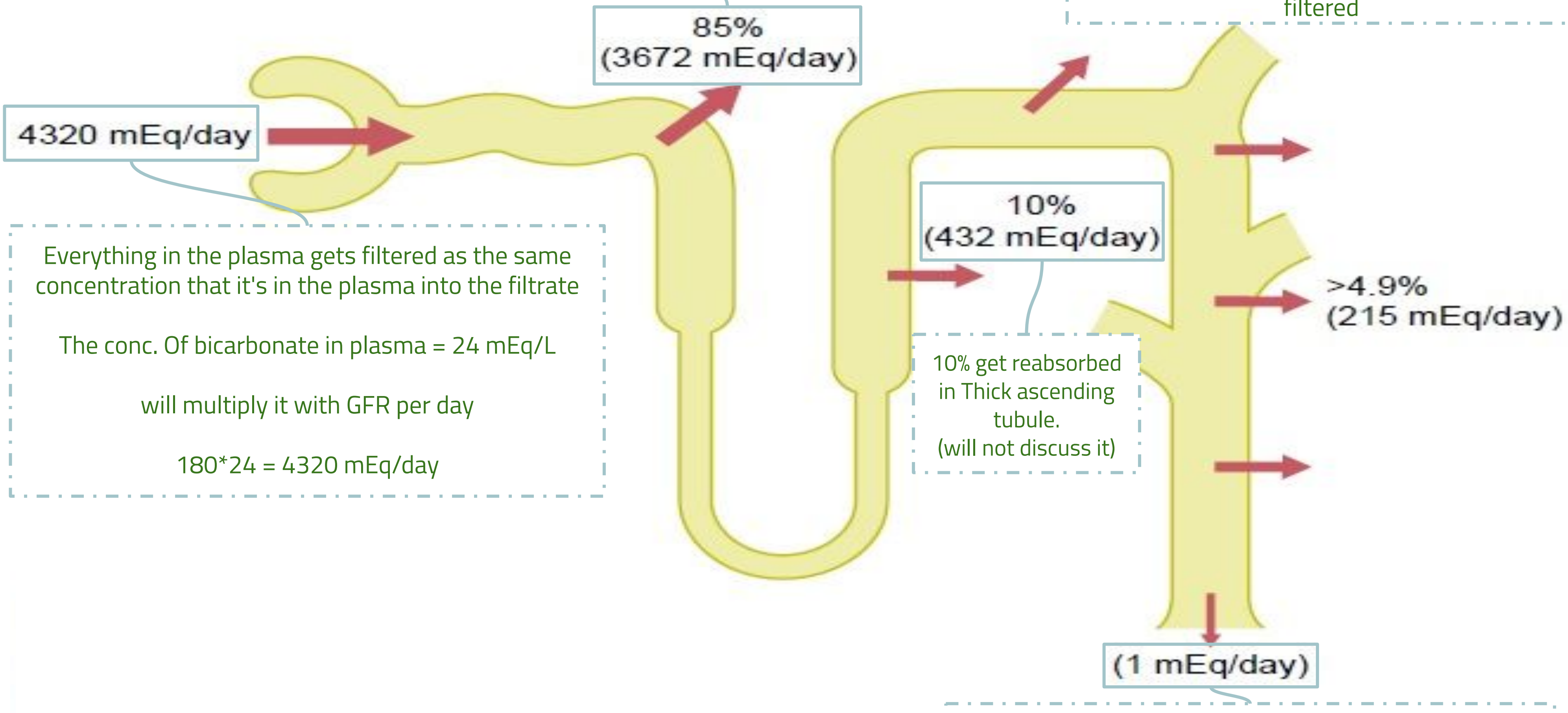
The kidney excretes acidic or alkaline urine by three process:

- Secreting H^+
- Reabsorbing HCO_3
- Generating "new" bicarbonate ions

Overview HCO_3^- Reabsorption by the Renal Tubules

Will the body allow the 4320 of Bicarbonate to be excreted in urine in one time? No because within minutes our body will be in acid state because we excrete more base, therefore Bicarbonate have to be reabsorbed.
In Proximal C.T 85% of HCO_3^- get reabsorbed.

Remain 10% Will be reabsorbed in distal part it will also get excreted depending on how much the body need it + the conc. of absorption. BUT usually
We reabsorb 99% of bicarbonate that get filtered



Everything in the plasma gets filtered as the same concentration that it's in the plasma into the filtrate

The conc. Of bicarbonate in plasma = 24 mEq/L

will multiply it with GFR per day

180*24 = 4320 mEq/day

10% get reabsorbed in Thick ascending tubule.
(will not discuss it)

Almost all HCO3 GET FILTERED get reabsorbed Because we are always in acid load rather than in a basic load.

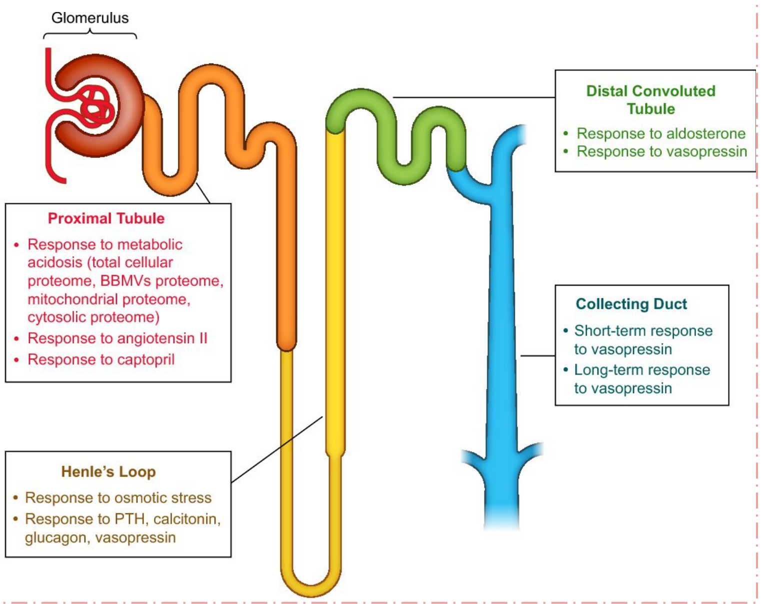
the amount of bicarbonate in the body before reaching the kidney is 4320 mEq/day, the amount excreted is only 1 mEq/day. This means that 99.9% of the bicarbonate is being reabsorbed by the body in different parts of the renal tubule. around 80-90% is reabsorbed occurs in the proximal tubule.

In PCT, LOH(A), and early DCT:
Na and H Counter Transport HCO_3 -Buffer System

In DCT and CT: Proton Pump
(Primary Active Transport)

In PCT, LOH(A), and late DCT:
PO_4 Buffer System

For Understanding:



How is HCO_3^- reabsorbed by the tubules?

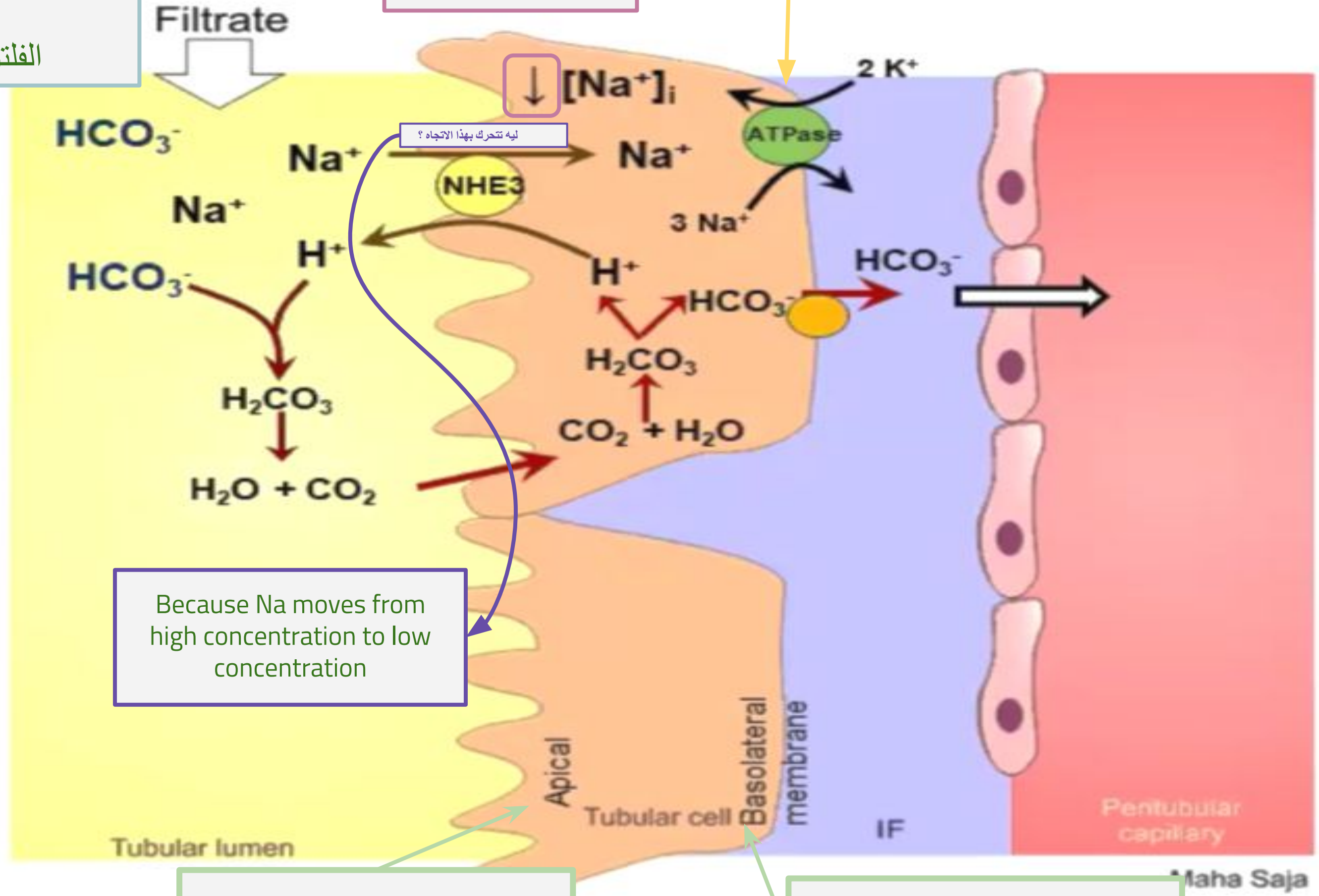
In PCT, LOH(a), and early DCT

Rich in Na and HCO_3^- and anything that can pass easily through the glomerular filtration barrier,
تركيز المواد اللي تقدر تخترق هالممبرين بيكون فيها
الفلتريت نفس تركيز البلازما

Secreted H+ binds to filtered HCO3- in the tubular lumen

Forming H2CO3 which dissociates into H2O & CO2

CO2 diffuses through tubular cell membrane and react with water forming H2CO3 inside the cell



Na /K pump
it's the imp. one in reabsorption why? because most of ions that get reabsorbed they depend on the gradient of Na+ which created by this pump.

الصوديوم قليل لأن
الpump يطلع 3 Na و
يدخل 2K

Because Na moves from high concentration to low concentration

Apical membrane which faces tubular lumen

Basolateral membrane that faces IF

Explanation

1

Because Na moves from **high** concentration (in tubular filtrate)
to **low** concentration (tubular cell) using a carrier molecule.
one of the carriers called sodium hydrogen exchanger
So it reabsorb Na, in exchange of Hydrogen (so it secretes hydrogen by secondary active transport).

2

Once hydrogen secreted into tubular lumen it will find HCO3- (Bicarbonate) they will bind together and form = H2CO3 (Carbonic acid).
as we know carbonic acid can dissociate specially in presence of Carbonic anhydrase enzyme.
CA enzyme is present on the surface of tubular cells so carbonic acid will dissociate into H2O + CO2

3

CO2 can easily diffuse across cell membrane.
Again inside the cell CO2 will bind to water and also inside the cell i have CA enzyme therefore Carbonic Acid (H2CO3) will be formed.
Again Carbonic acid will dissociate into (H+ , HCO3):
H+ —>will be secreted into lumen
HCO3 —> will be transported into IF by carrier, then from IF to blood by bulk flow.

4

The HCO3- that gets into the tubular cell, it's not the same HCO3- that gets into the blood, not the same molecule! But for each Bicarbonate that disappears from the lumen —> there is one Bicarbonate will appear in the blood. so we consider it reabsorbed by لفة جحا 😂

IF don't have H+ —> Reabsorption of HCO3- will NOT happen. So reabsorption of bicarbonate requires secretion of hydrogen.

We are not losing hydrogen in this process.

PCT cont…

This pattern of H^+ secretion occurs in the proximal tubule (PCT), the thick ascending segment of the loop of henle (LOH(a)), and the early distal tubule(DCT).

- The PCT reabsorbs "reclaims", 80 - 90% of the filtered HCO_3^-
- HCO_3^- reabsorption is linked to H^+ secretion.
- HCO_3^- is "Titrated" Against H^+ in the Tubules
- In case of no/little HCO_3^- in the lumen H^+ will bind to other buffers e.g. phosphate and ammonia resulting in the elimination of excess H^+ and generation of new HCO_3^-

1 Na+ and HCO_3^- is filtered in the glomerulus.

2 Renal tubule cells secrete H^+ in exchange for Na^+

3 CO_2 is formed by the reaction reaction of HCO_3^- and H^+ and diffuses into the tubule cell

4 CO_2 is converted back into HCO_3^- in the renal tubule cell

5 Na^+/HCO_3^- symporter carries Na^+ and HCO_3^- across basal membrane of tubule cell

What happens at the DCT & CT?

Explanation

you should know that the amount of bicarbonate that derived here is a little amount because 85% get reabsorbed in PCT.
as we know in DT there is different types of cell (principal cell,intercalated cell) here we will discuss intercalated cell and specially type a.

In the intercalated cell, there are **two pumps:**

1. H/k pump —> it secretes H+ and Reabsorbe K+
2. Hydrogen pump —> only secretes H+

يعني مردنا بنفرز هيدروجين

If the hydrogen finds HCO3 in the lumen —> it will bind with it and the same thing happens in PCT will happen here again.
But If the hydrogen DOESN'T find HCO3 in lumen —> it will be excreted by binding to another buffer which is phosphate buffer but phosphate buffer doesn't have the ability to do the same cycle it was done with carbonic acid (لفة جحا) so it will excrete it in the urine.

فالحالتين كالتالي:

1-repeat what happens in PCT if H find HCO3
2- get excreted in the urine.

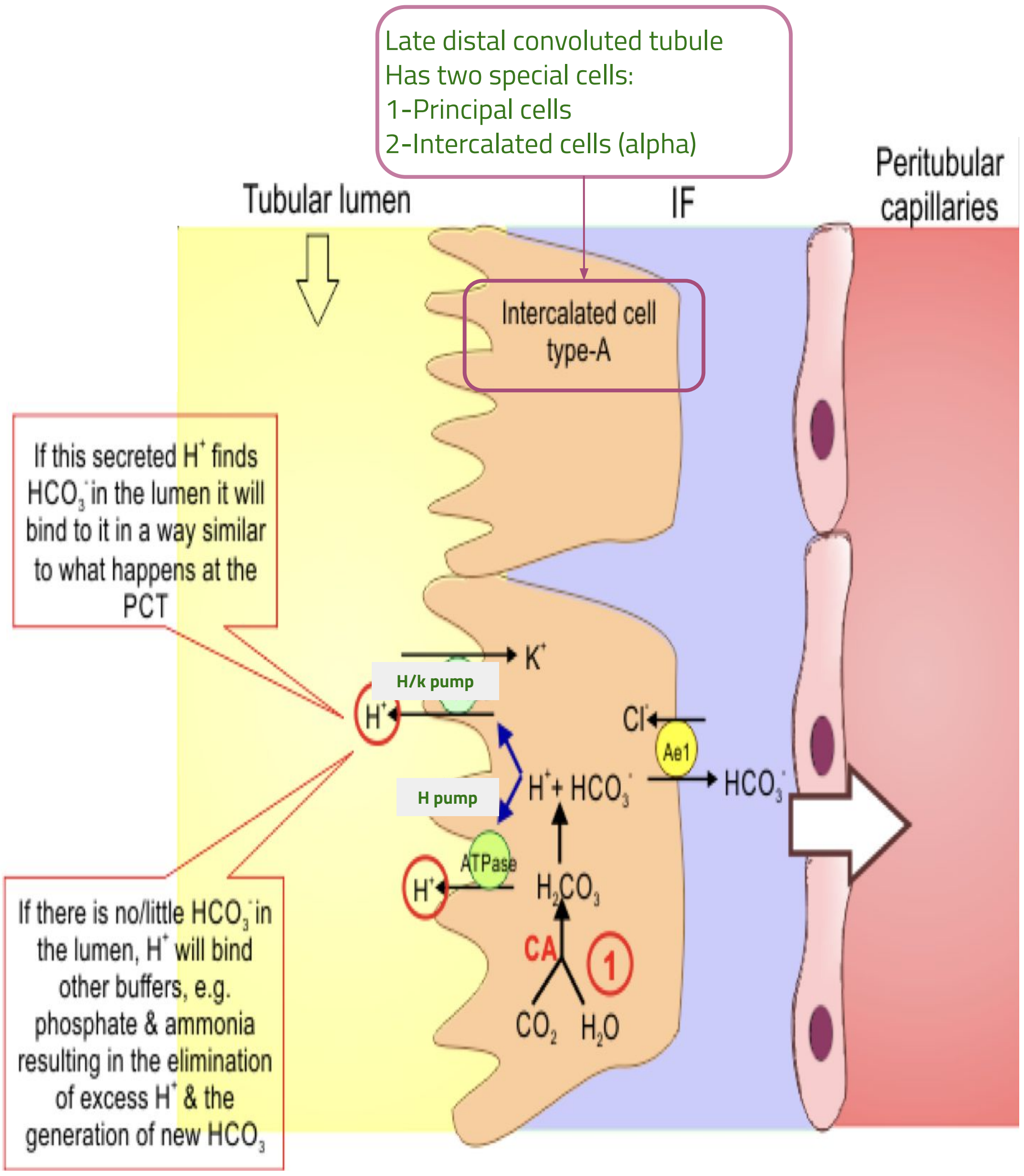
From where we got the Hydrogen inside intercalated cell?

from H2CO3 dissociation which also produce HCO3- with the hydrogen, then HCO3- gets reabsorbed into blood (we consider it new bicarb) and H+ get secreted into the lumen. (More details in slide 12)

يعني هايدروجين افرز، و Bicarbonateاعيد امتصاصه
فكأنه new molecules ، ليه؟ لأن ماقابله اختفاء لنفس المركب
اللي هو -HCO3 من الجهة المقابلة اللي هي Tubule!

And this is how the **kidney** generate new **HCO3-**

العلم قميل


Late distal convoluted tubule
Has two special cells:
1-Principal cells
2-Intercalated cells (alpha)

If this secreted H^+ finds HCO_3^- in the lumen it will bind to it in a way similar to what happens at the PCT

If there is no/little HCO_3^- in the lumen, H^+ will bind other buffers, e.g. phosphate & ammonia resulting in the elimination of excess H^+ & the generation of new HCO_3

late DCT and CT Cont...

HYDROGEN ION SECRETION

- The filtrate arriving DCT & CT is low in HCO3-

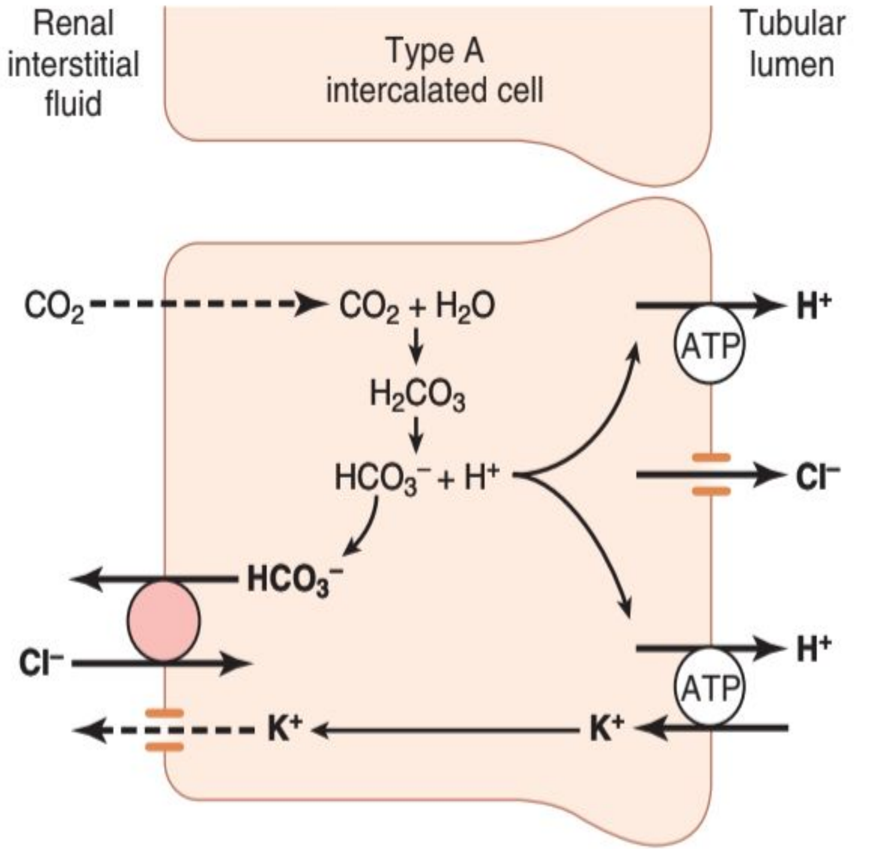
- The distal segments of the nephron are characterised by the presence of “intercalated cells” capable of **actively secreting H+** through H+-ATPase and H+-K+ ATPase present on their apical membrane **(Type-A intercalated cells).**

- Only a limited number of H+ can be excreted in its free form in urine.

- Lowest possible urine pH=4.5 → ≈ 0.04mmol/L of free H.

We cannot excrete urine more acidic than that because it will damage the epithelium

Late DCT and CT



α-Intercalated cell → Acid-secretion

β-Intercalated cell → Bicarbonate-secretion

Remember that intercalated Cells have H-ATPase and H/K-ATPase

Non-Bicarbonate Buffers in the Tubular Lumen?

How does the kidney excrete the extra H^+?

the extra H^+ secreted will need to be buffered in the tubular lumen

There are 2 main non- bicarbonate buffers in the tubular lumen

1 -Filtered

We have phosphate in ECF in the plasma, it will get filtered and will find it in Filtrate.

Phosphate Buffer System

Dihydrogen phosphate **Hydrogen phosphate act as conjugated base**

$H_2PO_4^-$ ⟷ HPO_4^{-2} + H^+

(Acid) (Base)

2 - Synthesized

The kidney is able to synthesize ammonia, and it work as a buffer by binding H

Ammonia Buffer System

Ammonium **Ammonia**

NH_4^+ ⟷ NH_3 + H^+

(Acid) (Base)

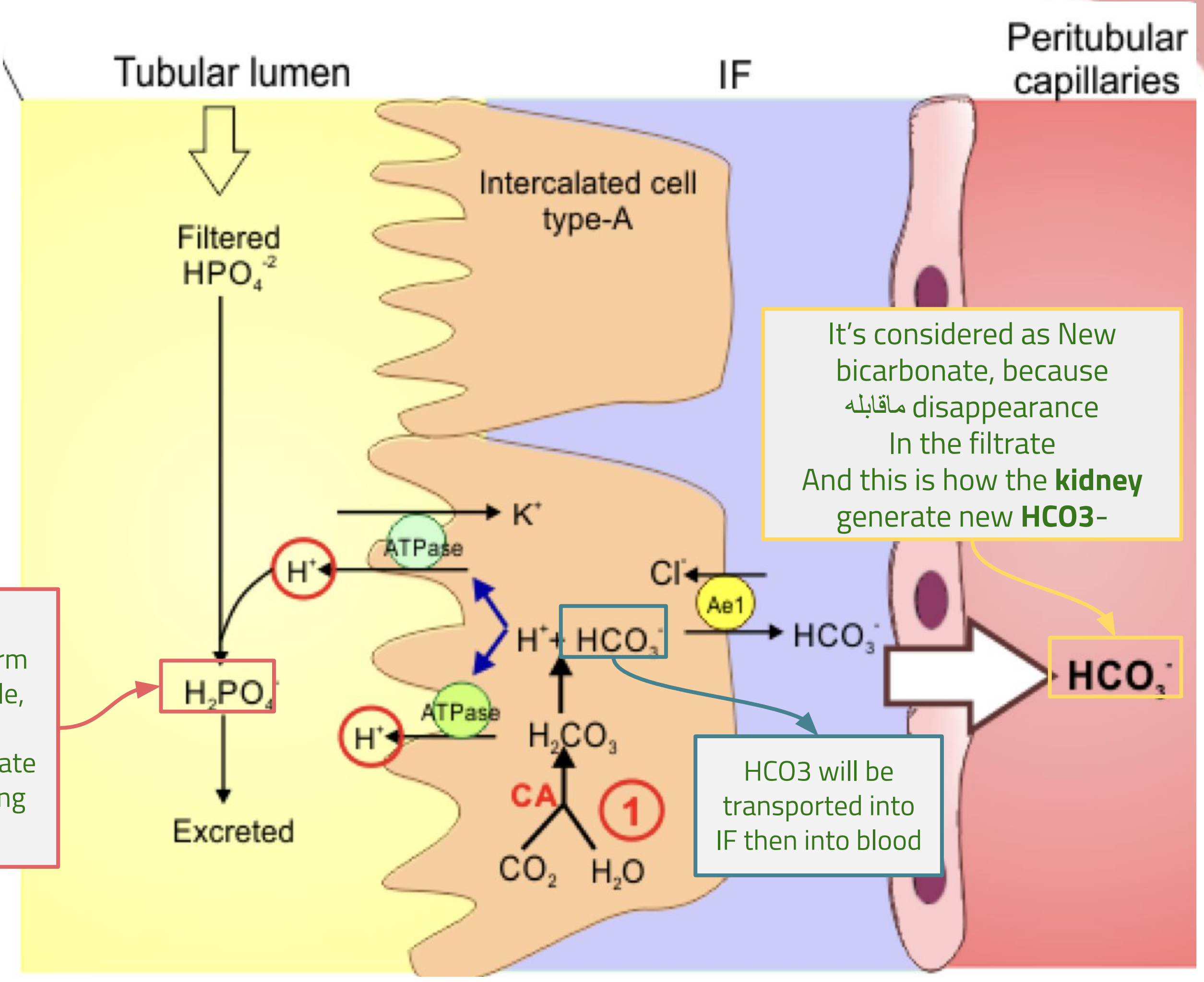
- # The Phosphate Buffer System

Excretion of H+ and Generation of New HCO_3^-

In DCT +collecting duct

-Excretion of H+ as phosphate is capable of handling a limited amount of H+ and will not be enough to rid the body of its daily acid load nor if there is unusually high acid production.

H+ will be secreted into lumen and it will find hydrogen phosphate (HPO4) to bind with it and form Dihydrogen phosphate which is a charged molecule, so it cannot across the cell membrane, Therefore it gets trapped into the lumen of the filtrate and then get excreted In the urine. so now i'm losing Hydrogen as well.

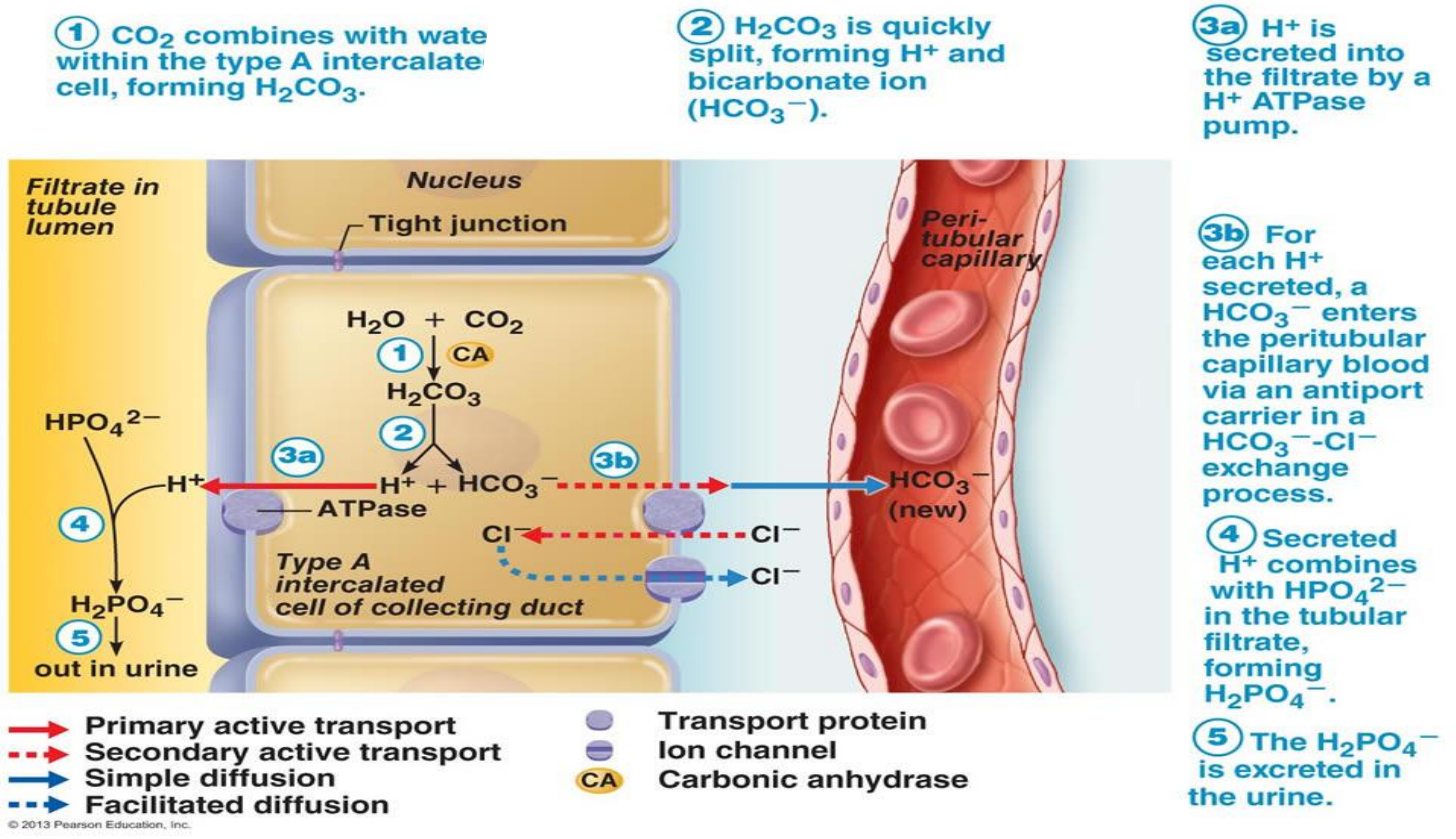


It's considered as New bicarbonate, because مقابله disappearance In the filtrate And this is how the **kidney** generate new **HCO3-**

HCO3 will be transported into IF then into blood

Guyton : buffering of secreted H+ by filtered phosphate (NaHPO4) → NaH2PO4
Note that a new HCO3- is returned to blood for each NaHPO4 that reacts with a secreted H+

Same mechanism but in different picture



① CO_2 combines with wate within the type A intercalate cell, forming H_2CO_3.

② H_2CO_3 is quickly split, forming H^+ and bicarbonate ion (HCO_3^-).

3a H+ is secreted into the filtrate by a H+ ATPase pump.

3b For each H+ secreted, a HCO_3^- enters the peritubular capillary blood via an antiport carrier in a HCO_3^--Cl^- exchange process.

④ Secreted H+ combines with HPO_4^{2-} in the tubular filtrate, forming $H_2PO_4^-$.

⑤ The $H_2PO_4^-$ is excreted in the urine.

• The Ammonia Buffer System

Renal tubular cell, especially PCT, are capable of generating ammonium (NH_4^+) “ammoniagenesis” which is then excreted in urine carrying with it H^+.

The rate of ammoniagenesis can be modified according to the needs of the body.

Quantitatively, the ammonia buffer system if more important than the phosphate buffer system for H^+ excretion in urine.

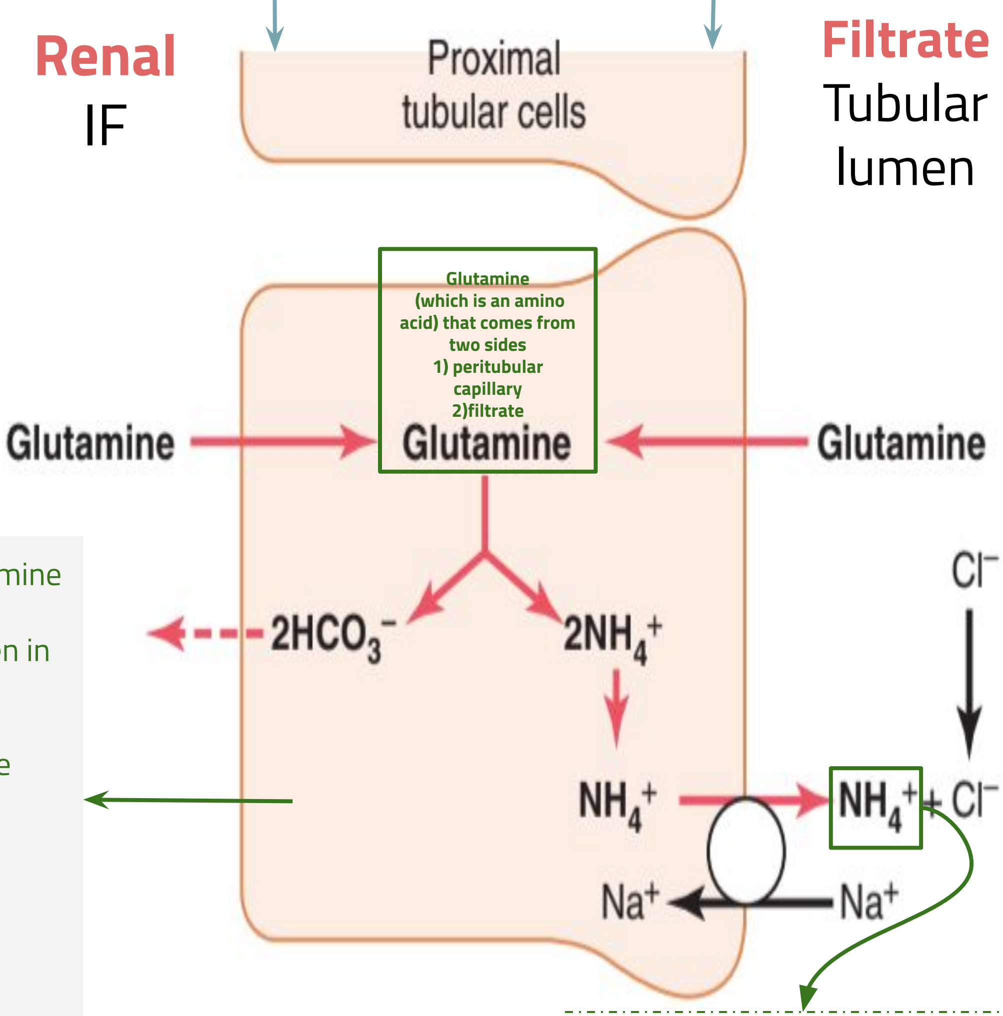
It is the most important system in case of acidosis.

Proximal convoluted cells have the ability to degrade the glutamine into : **2**HCO3 + **2**NH4
2 ammonium molecules (2NH4) get secreted into tubular lumen in exchange for Na “they think this process happens by using the same carrier of hydrogen: Na/H exchanger”
otherwise Two Bicarbonate (HCO3-) will be reabsorbed into the blood.
It's considered a **new molecules again**, because ما قابلها disappearance of HCO3- from the tubular lumen.
-What is the strongest buffer of these two (phosphate, ammonia) in generation new Bicarbonate?
Ammonia buffer, because it generate two HCO3 from one glutamine

انتبهوا الرسمة بياناتها عكس باقي الصفحات

Basolateral membrane that faces IF

Apical membrane which faces tubular lumen



Glutamine (which is an amino acid) that comes from two sides
1) peritubular capillary
2)filtrate

When it’s excreted in the urine it’s considered as i’m losing H+ also

Guyton :production and secretion of ammonium ion (NH4+) by proximal tubular cells. Glutamine is metabolized in the cell, yielding NH4 and bicarbonate. The NH4 is secreted into the lumen by a Na - NH_4 exchanger. For each Glutamine molecule metabolized two NH_4^+ are produced and secreted and two HCO_3^- are returned to the blood.

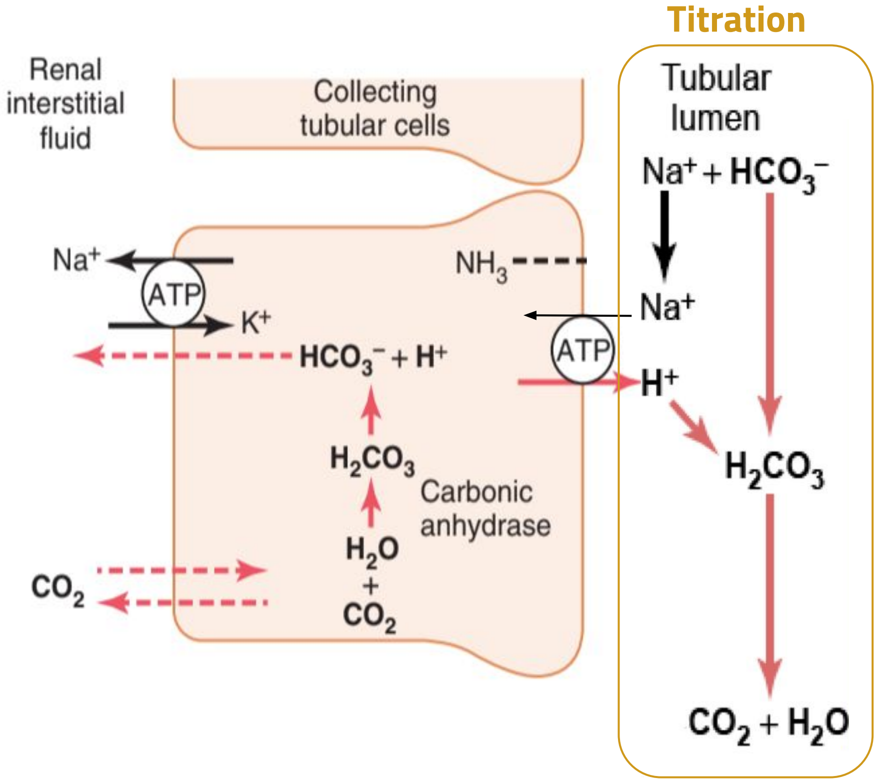
From boys slides

HYDROGEN ION SECRETION

Guyton :Buffering of Hydrogen ion secretion by ammonia (NH_3) in the collecting tubules. Ammonia diffuses into the tubular lumen, where it reacts with secreted H^+ to form NH_4^-, which is then excreted. For each NH_4^+ excreted, a new HCO_3^- is formed in the tubular cells and returned to the blood.

We Can Generates new HCO_3^- by two mechanisms:

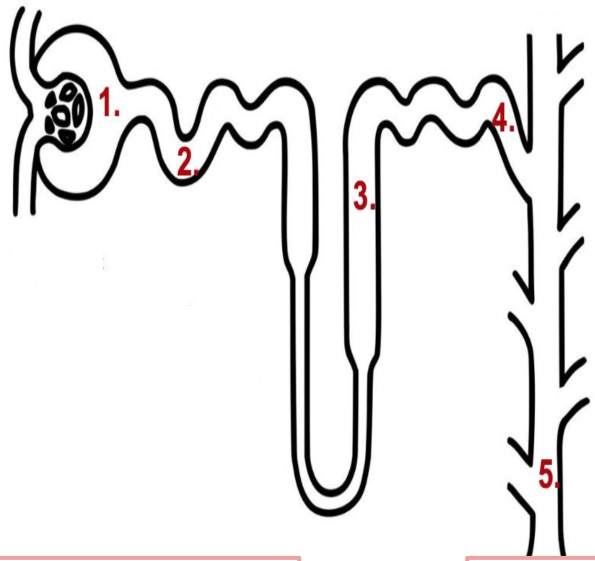
1) When H+ is secreted by the Intercalated cells, and it doesnt find HCO_3^-, so it starts binding to non-bicarbonate buffers such as phosphate buffer, which will lead to a newly formed HCO3.
2) By Ammoniagenesis: due to the breakdown of Glutamine, which will give 2HCO3.



HCO3– Is “Titrated” Against H+ in the Tubules

From female slides

The overall scheme of renal excretion of Acids & Bases



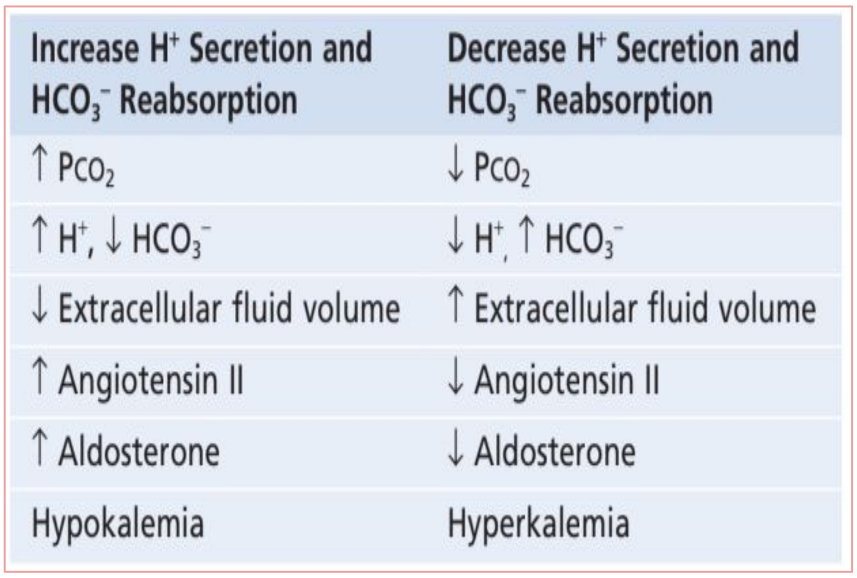
To excrete Acid:

1- Freely filter HCO_3^-
2- Reabsorb the majority of filtered HCO_3^-
3- Reabsorb some additional HCO_3^-
4- Secrete H^+ (titrate filtered bases, i.e. HPO_4^{-2}) and secrete NH_4^+
5- Excrete acidic urine containing NH_4^+ and H2PO4 -

To excrete Base:

1- Freely filter HCO_3^-
2- Reabsorb the majority of filtered HCO_3^-
3- Reabsorb some additional HCO_3^-
4- Secrete some HCO_3^-
5- Excrete alkaline urine containing HCO_3^-

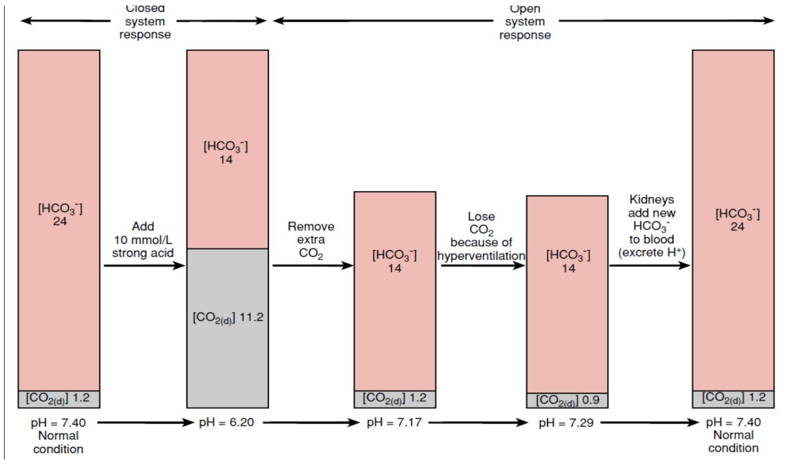
Factors Affecting H+ Secretion and HCO3 - Reabsorption



Increase H^+ Secretion and HCO_3^- Reabsorption	Decrease H^+ Secretion and HCO_3^- Reabsorption
↑ PCO_2	↓ PCO_2
↑ H^+, ↓ HCO_3^-	↓ H^+, ↑ HCO_3^-
↓ Extracellular fluid volume	↑ Extracellular fluid volume
↑ Angiotensin II	↓ Angiotensin II
↑ Aldosterone	↓ Aldosterone
Hypokalemia	Hyperkalemia

From boys slides

The HCO_3/CO_2 System. This system is remarkably effective in buffering added strong acid in the body because its open.



MCQ & SAQ

Q1: The importance of bicarbonate buffer system in

A. ICF
B. ECF
C. Urine
D. A and B

Q2: The normal values of PCO_2 are in the range

A. 25- 35 mmHg
B. 20- 45 mmHg
C. 15 - 25 mmHg
D. 35 - 45 mmHG

Q3: The CO_2 component of the buffer is regulated by

A. Kidney
B. Heart
C. Lung
D. Liver

Q4: which powerful system that works within hours to days

A. Respiratory System
B. Bicarbonat System
C. Phosphate
D. Renal System

Q5: Which of the following is capable of generating ammonium

A. PCT
B. DCT
C. CT
D. LOH

Q6: most of the reabsorption takes place in

A. DCT
B. PCT
C. CT
D. LOH

answer key:
1: B
2: D
3: C
4: D
5: A
6: B

1- How does the kidney excrete acidic or basic urine ?

2- Why is the Bicarbonat most important buffer system in the ECF?

3- How does the kidney excrete the extra H^+?

A1: secreting H^+ , Reabsorbing HCO_3 , Generating "new" bicarbonate ions

A2: 1-The CO_2 component of the buffer is regulated by the lungs , 2-The HCO_3^- component of the buffer is regulated by the kidneys

A3: the extra H^+ secreted will need to be buffered in the tubular lumen, by the Phosphate Buffer System or the Ammonia Buffer System

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