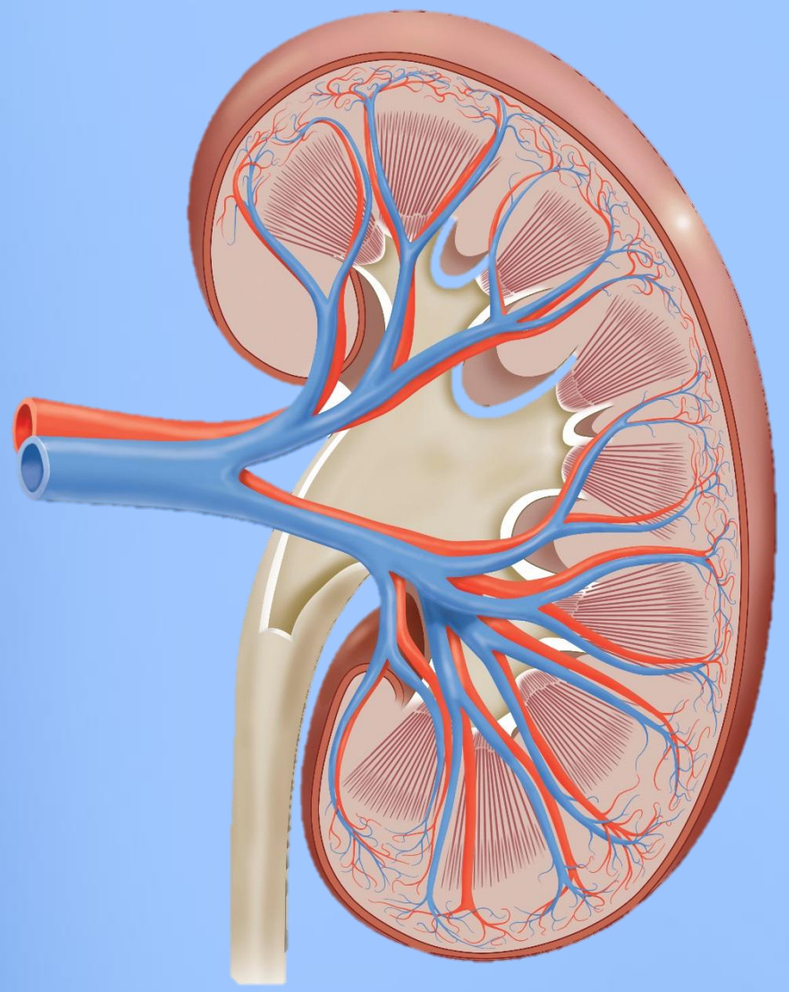
9&10

BASICS OF ACID BASE BALANCE & BUFFER SYSTEMS



Renal Block

Objectives

Basics of Acid-base balance:

- Define: acid and base.
- Explain what is meant by strong and weak acids and bases
- List and identify the names/formulas for the common strong acids and strong bases.
- To explain the role of Henderson-Hasselbalch equation in acid-base regulation

Buffer systems:

- To define buffer system and discuss the role of blood buffers and to explain their relevant roles in the body
- To describe the role of kidneys in the regulation of acid-base balance
- To describe the role of lungs in the regulation of acid-base balance

Basics of Acid Base Balance

Overview of pH

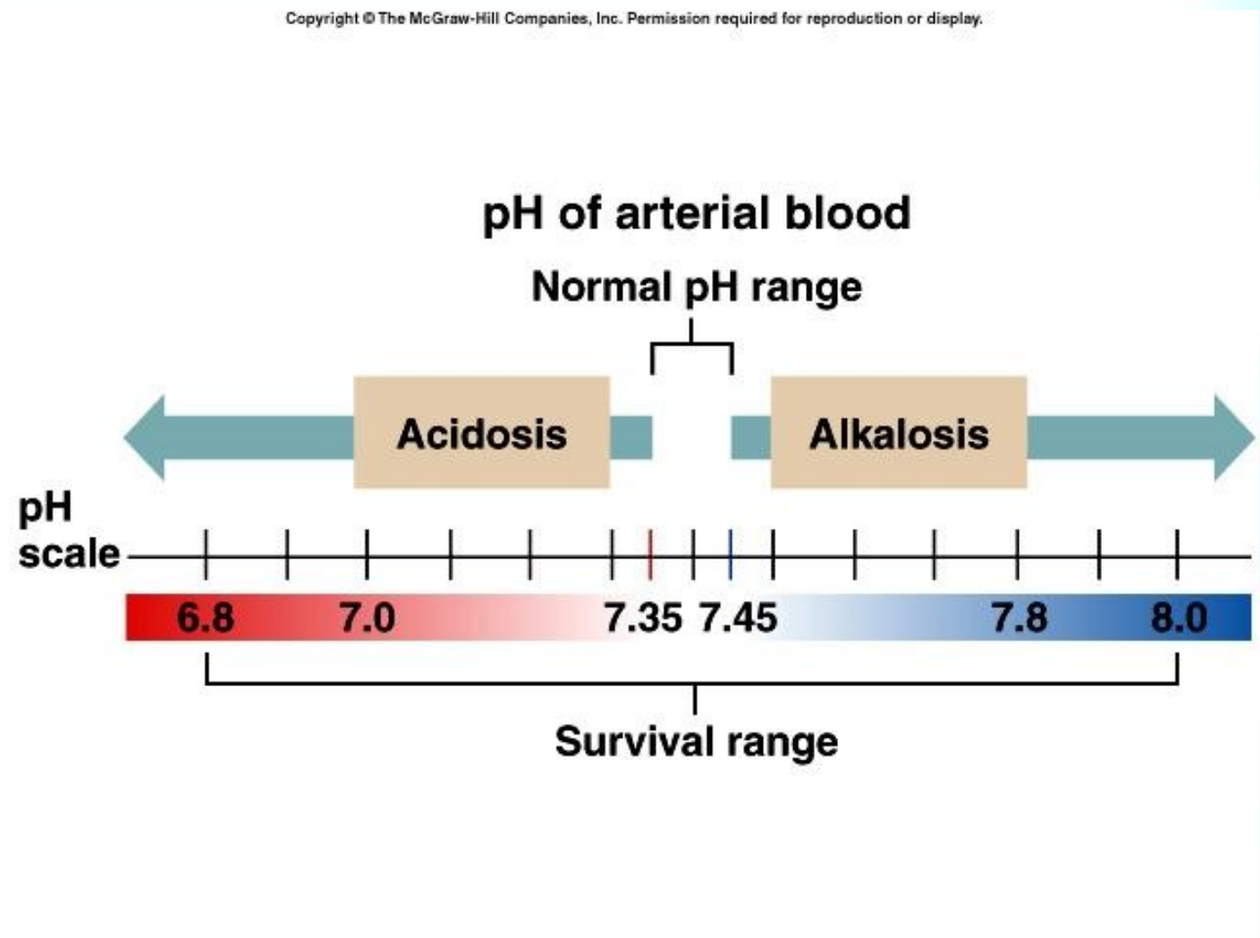
What pH represent?
H+ concentration in the blood

What is the normal range of pH?
- in general: 0-14
- in the blood: 7.35-7.45
- Extracellular fluid (ECF): 7.4

What is the type of blood sample should be taken to measure pH and Why?
Arterial blood sample (not venous), because it represents the actual contents of blood such as Oxygen, nutrients.. Etc.

Does pH in the body change?
Yes, like exercise body will add some hydrogen to blood through lactic acid and change pH.

How can we calculate the pH?
pH= 1/H+ concentration log
OR
pH= - log [H+]



What is the survival range of pH in the blood?
Between 6.8 and 8. More or less will lead to death

When we said it is acidosis or alkalosis?
-pH less than 7.35 (acidosis)
-pH more than 7.45 (alkalosis)

Acids and Bases

What acids and bases?

-Acids are **H+ donors**
-Bases are **H+ acceptors**

Why acids more than bases in our bodies?

1.Food that contain **proteins** and **lipids** are rich in acids

2.The end cellular metabolism in mitochondria produced **CO2** which **source of H+** from the following reaction:
$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3$

Why venous blood is more acidic than arterial?

Because it has higher **CO2 concentration** than arterial blood

Why pH tightly regulated and small changes in pH is a serious condition?

-Most enzymes work only in specific pH (change in pH → enzymes become inactive)
-Change in pH cause disturbance in electrolytes - Can affect some hormones
-**Acidosis** can cause depression of synaptic ending and lead to coma such as a patient with **diabetes ketoacidosis and Hypercalcaemia**
-Alkalosis can cause **convulsion , muscle twitching, tetany and hypocalcemia**

Strong and weak acids and bases

- **Strong acid** = **HCL** (complete dissociation)
- **Weak acid** = **Lactic acid,CO2,H2CO3** "Carbonic acid" (Partial dissociation)
- **Strong base** = **NaOH** (complete dissociation)
- **Weak base** = **NaHCO3,HCO3** (Partial dissociation)

Buffer systems

Systems that regulate pH

-Chemical buffer system: (first line)
Buffer system (**immediately**)
-Physiological buffer system: (second line)
1.Respiratory system (**from minutes to hours**)
2.Renal system (**from hours to days**) **The most effective regulator of pH**

The component of chemical buffer system

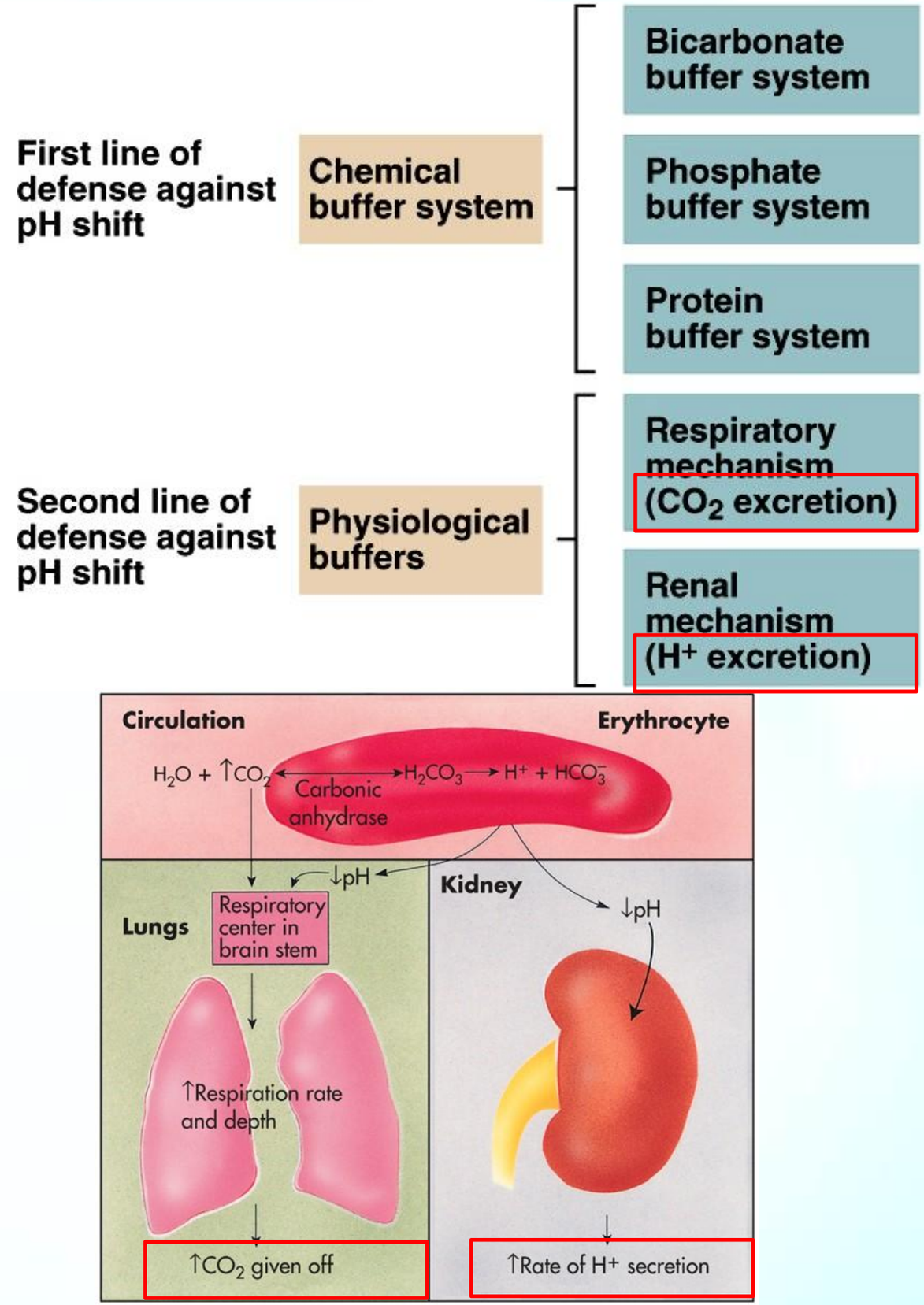
1. Bicarbonate buffer (intracellular and **extracellular**)
2. Phosphate buffer (intracellular and **renal tubule fluid**)
3. Protein buffer (**the most important intracellular**)

What is the goal of chemical buffer systems?

Convert **strong acids and bases** to **weak acids and bases** to maintain blood pH

The most important feature of chemical buffers

pH of buffer must be the same or very close to the pH of sites that buffer work in. to observe the changes in pH.



• Bicarbonate buffer

What are the components of bicarbonate buffer system?

-**Sodium bicarbonate**: NaHCO3 regulated by kidney

-**Carbonic acid:** H2CO3 regulated by lungs through equation:

CO2 + H2O → H2CO3

Why it is the most important extracellular buffer system?

Because it regulated by kidney and lungs

What is the concentration of HCO3 in the blood and what it is called?

Its concentration in blood equals = 27mEq/L and is called alkali reserve.

How bicarbonate buffer work?

We must have acid and base to react with each other. Then:

$$HCl \text{ (strong acid)} + NaHCO_3 \leftrightarrow H_2CO_3 \text{ (week acid)} + NaCl$$

OR

$$NaOH \text{ (strong base)} + H_2CO_3 \leftrightarrow NaHCO_3 \text{ (weak base)} + H_2O.$$

How can we calculate blood pH through bicarbonate buffer?

By **Handerson-Hasselbalch equation:**

$$pH = 6.1 + \log \frac{HCO3-}{0.03 \times PCO2}$$

Note that 6.1 represent pH of the buffer not the blood

• Phosphate buffer

What are the components of bicarbonate buffer system?

-Hydrophosphate: HPO4 which bind to H+ to Increase pH

-Dihydrophosphate: H2PO4 which bind to OH to Decrease pH

$$H^+ + HPO_4^{2-} \leftrightarrow H_2PO4^-$$

$$OH^- + H_2PO_4^- \leftrightarrow H_2O + H_2PO_4$$

pH of phosphate is around 5 (acidosis) because of that it works inside the cell

Why it is the most important kidney or renal tubules buffer system?

Because it has pH that so close to the pH of fluid in the tubules

• Proteins buffer

-Hemoglobin:

Carboxyl group gives H+ "Decrease pH"

Amino group accept H+ "Increase pH"

-Plasma proteins

-Intracellular proteins (the most important intracellular buffer)

the most important intracellular buffer as follow

1)Intracellular proteins buffer

2)Phosphate buffer

3) Bicarbonate buffer

Respiratory mechanism

What are the components of system?
The only component regulated here **is CO2 (carbon dioxide)** which is **volatile acids**.
It cannot deal with **fixed acids** such lactic acids that accumulate in skeletal muscles.
(Fixed acids is regulated by kidneys)

What is the general mechanism?
pH can be adjusted by changing **RATE** and **DEPTH** of breathing.
Patient with acidosis → Hyperventilation → wash out CO2 → increase pH
Patient with alkalosis → Hypoventilation → retain CO2 → Decrease pH

What happened if a healthy person has FAST hyperventilation?
He will stop ventilation after 15 seconds because amount of CO2 reduced and **chemoreceptors** in the brain will observe this reduction. Therefore, it will inhibit ventilation.

What happened if a healthy person has chronic hyperventilation?
Patient with **Anorexia** will develop alkalosis due to reduction in CO2.

Renal mechanism

What is the normal secretion of H+ and reabsorbation of HCO3 per day?

Secretion H+ = 4400 mEq/day

Filtration HCO3 = 4320 mEq/day

So, the 80 that remains must be titers by ammonia and phosphate buffer systems

What is the general mechanism?

Secretion of H+:

1.Sodium/H+ counter transport **(PCT, Thick ascending loop and early DCT)**

2.H+ pump **(Late DCT and collecting ducts)** **"phosphate buffer"**

3.Secretion of H+ with ammonia **"ammonia buffer"**

Reabsorbation of HCO3:

1.Reabsorbation of 99% of filtered HCO3 **(PCT, Thick ascending loop and early DCT)**

2.Generate a new one HCO3 by intercalated cells **(Late DCT and collecting ducts)** **"phosphate buffer"**

3.Generate new two HCO3 from glutamine **"ammonia buffer"**

SECRETION OF H+ AND REABSORPTION OF HCO3-

H+ secretion and HCO3- reabsorption occur in **all parts of tubules** EXCEPT:
1- descending and
2- thin ascending loop of Henle.
Keep in mind that for each HCO3- reabsorption, a H+ must be secreted.

1

Bicarbonate is filtered in glomeruli

2

tubules secrete H+ by Na-H Counter-transport (secondary active transport)

3

H+ is combined with HCO3- to form Carbonic acid which is converted to Co2 + H2O by carbonic anhydrase

4

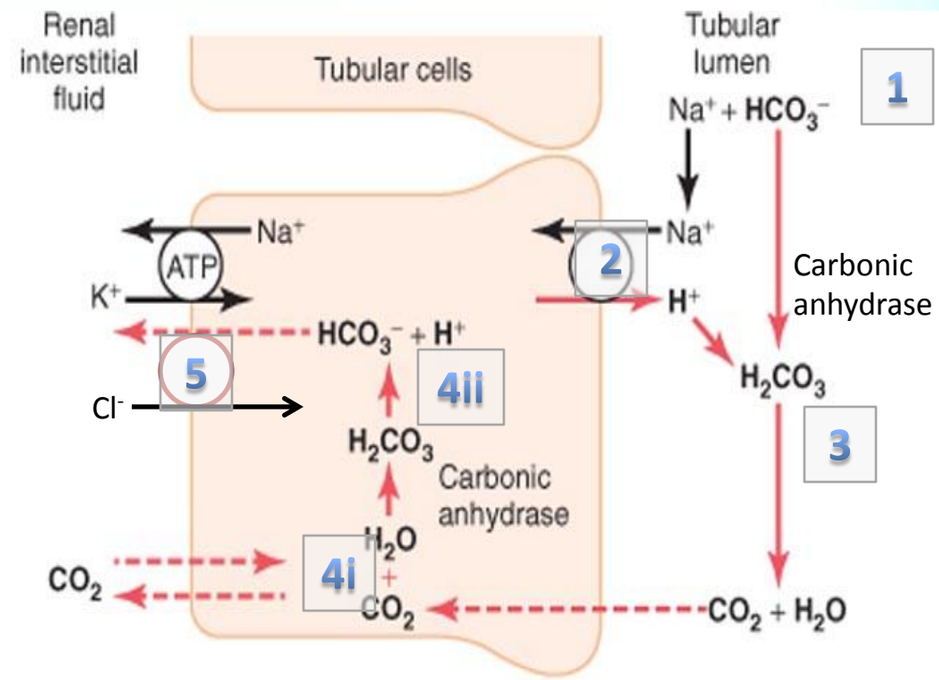
CO2 diffuses into the cell passively and

i- combines again with H2O by carbonic anhydrase to form carbonic acid which

ii- dissociates to H+ and HCO3-

5

H+ is excreted into the lumen (step 1) and HCO3- backs into the circulation by counter-transport with Cl.



- Carbonic anhydrase is an enzyme that combines HCO3- with H+ to make H2CO2. And dissociates H2CO3 to H+ and HCO3-
- Carbonic anhydrase inhibitors will create alkaline urine > body won't be able to excrete H+ and reabsorbed H2CO3. (Will be discussed in 1st pharmacology lecture)
- In renal failure the body won't be able to do this function, which result of acidosis.

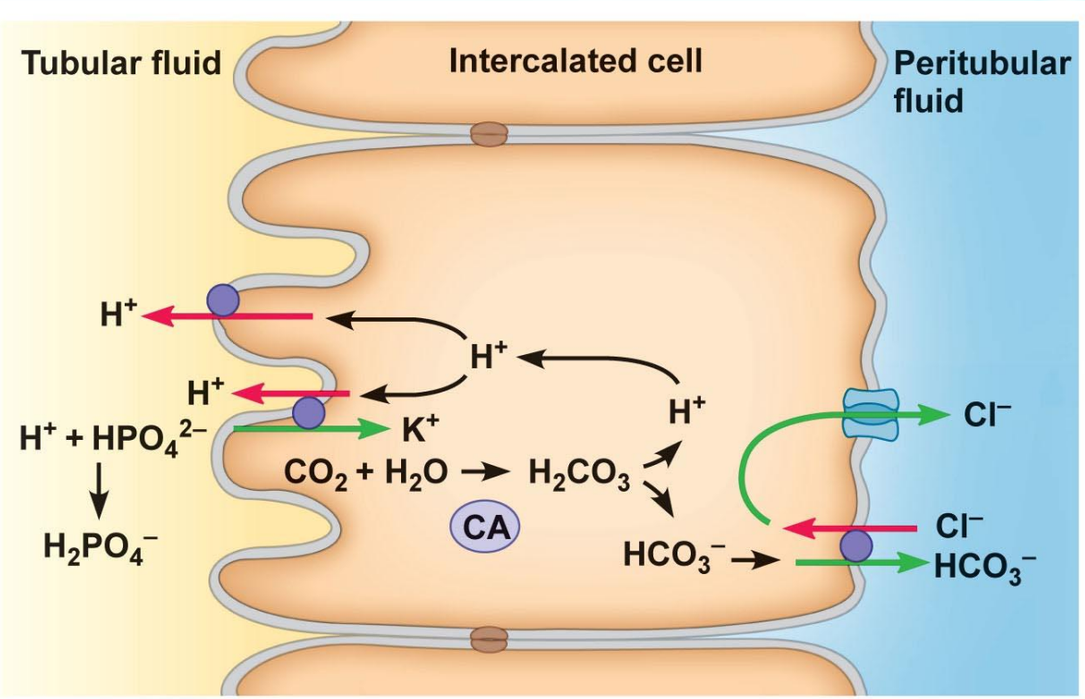
In circulation : reabsorption of HCO3- by counter – transport with Cl.
In the tubules lumin : reabsorption of HCO3- by counter – transport with Na.

HOW THE KIDNEY DOES SYNTHESIS A NEW BIOCARBONATE?

Why there is a buffer system for tubules by ammonia and phosphate?
Because H+ reduced tubular pH 4.5. This is the lower limit that can be achieved in normal kidneys. Further decrease will cause tubular acidosis.

What is the most important buffer of renal tubules? Ammonia or phosphate?
Ammonia because excreted two H+ and formation two HCO3

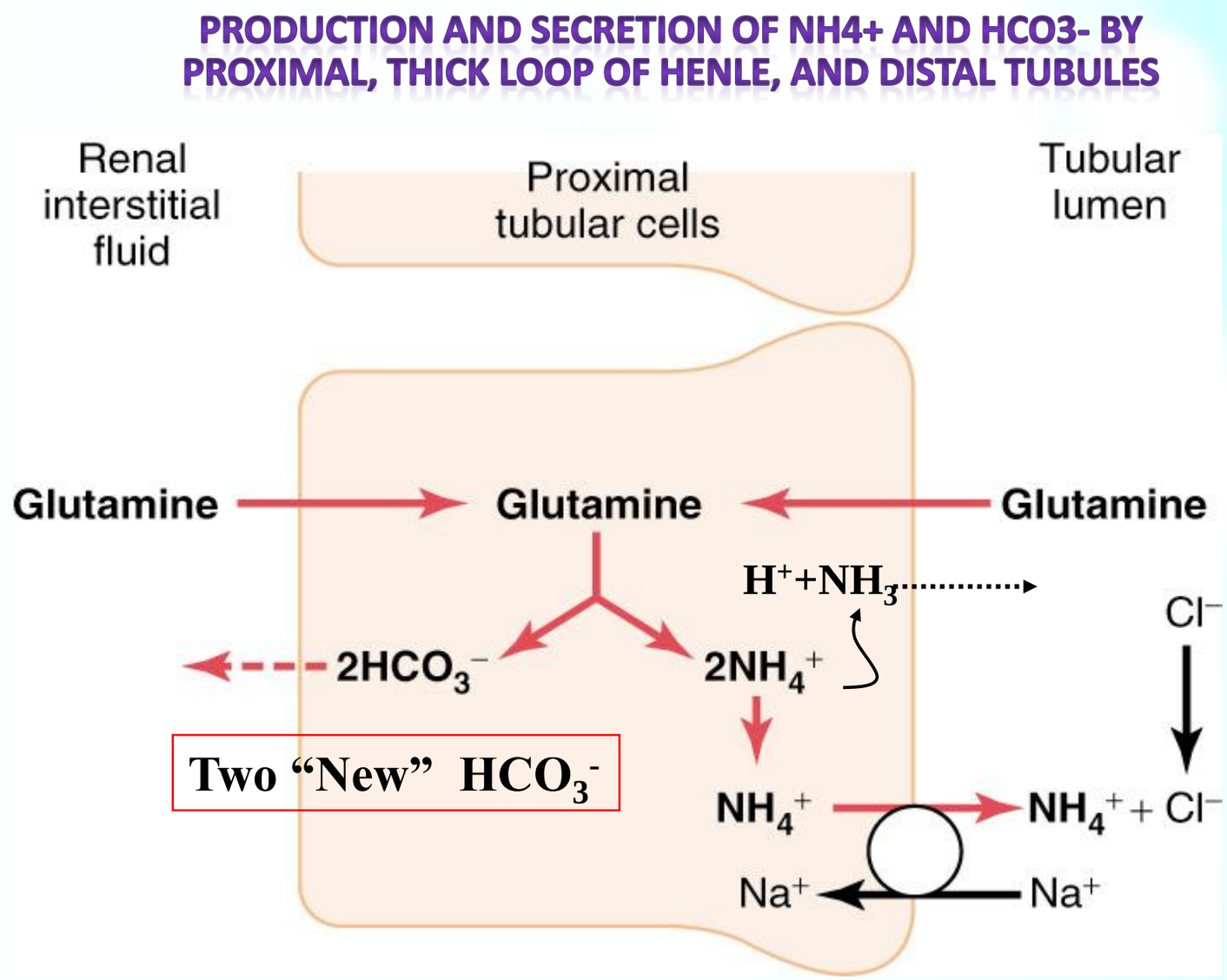
- No filtrated Bicarbonate in tubules
- CO2 binds to H2O to form H2CO3
- H2CO3 dissociates to bicarbonate and H+
- Bicarbonate is secreted back to blood as “new bicarbonate synthesized by metabolism”
- H+ is pumped into the tubular fluid. And it will bind to monohydrate phosphate (buffer of tubules)



Ammonia

Ammonia buffers H+ and form Ammonium

Acidosis → metabolize of glutamine into Two NH3 (ammonia) and Two HCO3 → Two H+ will bind with two NH3 to form two NH4 (ammonium) → Secreted of NH4 to tubules → NH4 bind with Cl to form ammonium chloride → excreted with urine



MCQS

1-What pH represent?
A-CO_2 concentration
B-HCO_3 concentration
C-H^+ concentration
D-OH^- concentration

2-Which of the following is a strong base?
A-HCl
B- NaOH
C-HCO_3
D-H_2CO_3

3-A patient with acidosis. He may develop:
A-Coma
B-Convlusion
C-Tetany
D-muscle twitching

4-Venous blood is more acidic than arterial blood due to:
A-CO_2 concentration
B-HCO_3 concentration
C-H^+ concentration
D-OH^- concentration

5- Which of the following is a protein buffer:
A-Albumin
B-Myosin
C-Actin
D-Hemoglobin

6-generation of new HCO_3 take place in:
A- PCT
B- DCT
C- Collecting ducts
D- Intercalate cells

7-Which of the following is a part of mechanism of phosphate buffer?
A- generation of two HCO_3
B- generation of two HPO_4
C- generation of one HCO_3
D- generation of one HPO_4

8-Ammonia will excreted in the urine as:
A-Ammonium
B-Ammonia
C-Ammonium phosphate
D-Ammonium chloride

Ans: 1-C, 2-B, 3-A, 4-A, 5-D, 6-D, 7-C. 8-D,