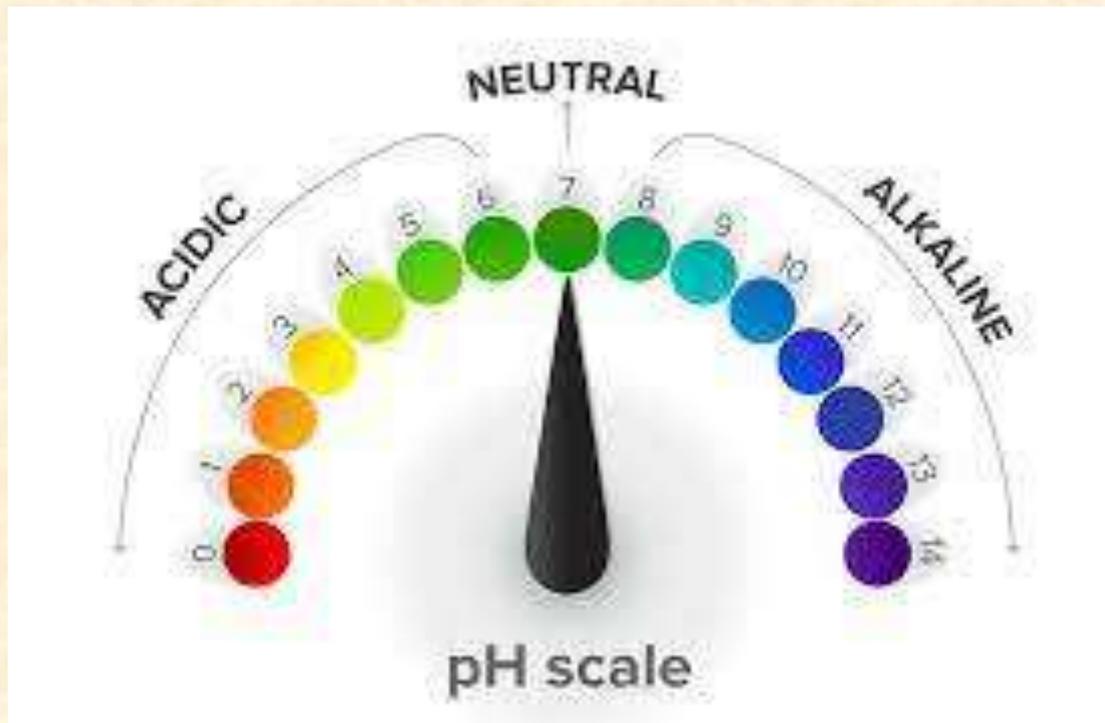


ACID BASE BALANCE BY DR/ HEBA KAREEM



Acid-Base balance

□ Acid is a substance whose **dissociation in water releases hydrogen ions (H⁺)** Produces more acidic solution & decrease in pH $\text{HCL} \longrightarrow \text{H}^+ + \text{Cl}^-$

□ A base **releases hydroxyl ions (OH⁻)** in aqueous solution.

This results in increase in pH of the solution

□ $\text{NaOH} \longrightarrow \text{Na}^+ + \text{OH}^-$

Amphoteric substances

Some substances, such as **amino acids & proteins,**
act acids as well as bases

Maintenance of blood pH

- The normal pH of the blood is maintained in the narrow range of 7.35- 7.45 (slightly alkaline).
- The body has developed three lines of defense to regulate the body's acid-base balance.
- 1- Blood buffers
- 2- Respiratory mechanism
- 3- Renal mechanism
- Blood buffers:
- A buffer may be defined as a solution of a weak acid & its salt with a strongbase

Blood contains three buffer systems

- Bicarbonate buffer
- Phosphate buffer
- Protein buffer
- Bicarbonate buffer system:
- Sodium bicarbonate & carbonic acid (NaHCO_3^- H_2CO_3) is the most predominant buffer system of ECF.
- Carbonic acid dissociates into hydrogen and bicarbonate ions.



- **The blood pH 7.4, the ratio of bicarbonate to carbonic acid is 20: 1**
- **The bicarbonate concentration is much higher (20times) than carbonic acid in the blood.**
- **This is referred to as alkali reserve.**

Respiratory mechanism for pH regulation

- **A rapid mechanism.**
- **This is achieved by regulating the concentration of carbonic acid (H₂CO₃) in the blood.**

The large volumes of CO₂ produced by the cellular metabolic activity. All of this CO₂ is eliminated from the body in the expired air via the lungs



The respiratory centre is highly sensitive to changes in the pH of blood.

Decrease in blood pH causes hyperventilation to blow off CO₂ & reducing the H₂CO₃ concentration

- Respiratory control of blood pH is rapid but only a short term regulatory process, since hyperventilation cannot proceed for long.

Hemoglobin as a buffer

- Hemoglobin binds to H^+ ions & helps to transport CO_2 as HCO_3^- with a minimum change in pH.
- In the lungs, hemoglobin combines with O_2 , H^+ ions are removed which combine with HCO_3^- to form H_2CO_3 & is dissociates to release CO_2 to be exhaled.

Generation of HCO_3^- by RBC

- Due to lack of aerobic metabolic pathways, RBC produce very little CO_2 .
- The plasma CO_2 diffuses into RBC along the concentration gradient, it combines with water to form H_2CO_3 by **Carbonic anhydrase**.
- In RBC, H_2CO_3 dissociates to produce H^+ & HCO_3^-
- The H^+ ions are buffered by Hemoglobin.
- As the concentration of HCO_3^- increases in the RBC, it diffuses into plasma along with concentration gradient, in exchange for Cl^- ions, to maintain electrical neutrality.

This is referred to as chloride shift, helps to generate

HCO_3^- .

Plasma

CO_2

HCO_3^-

Cl^-

Erythrocyte

$\text{CO}_2 + \text{H}_2\text{O}$

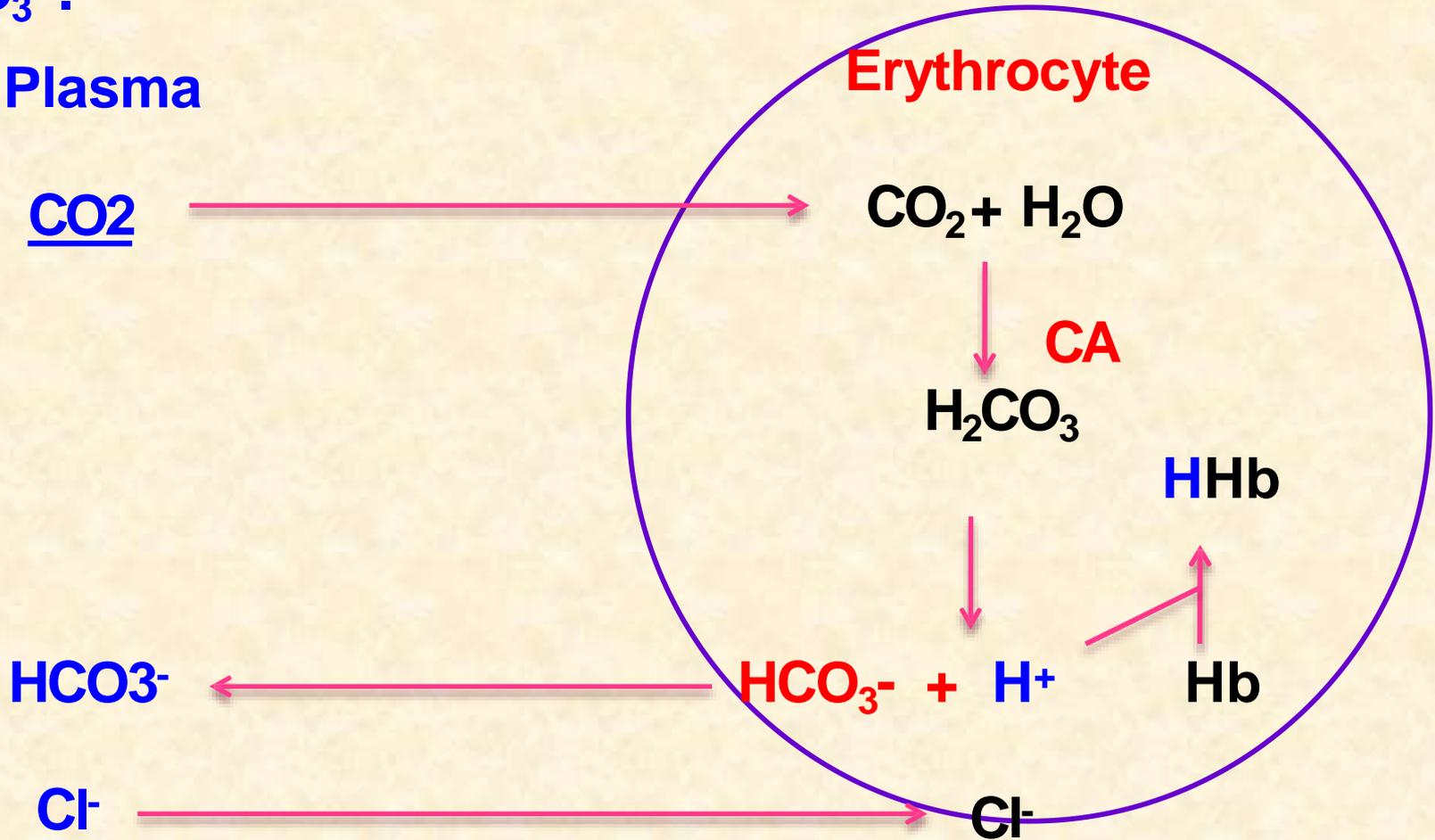
\downarrow CA
 H_2CO_3

$\text{HCO}_3^- + \text{H}^+$

HHb

Hb

Cl^-



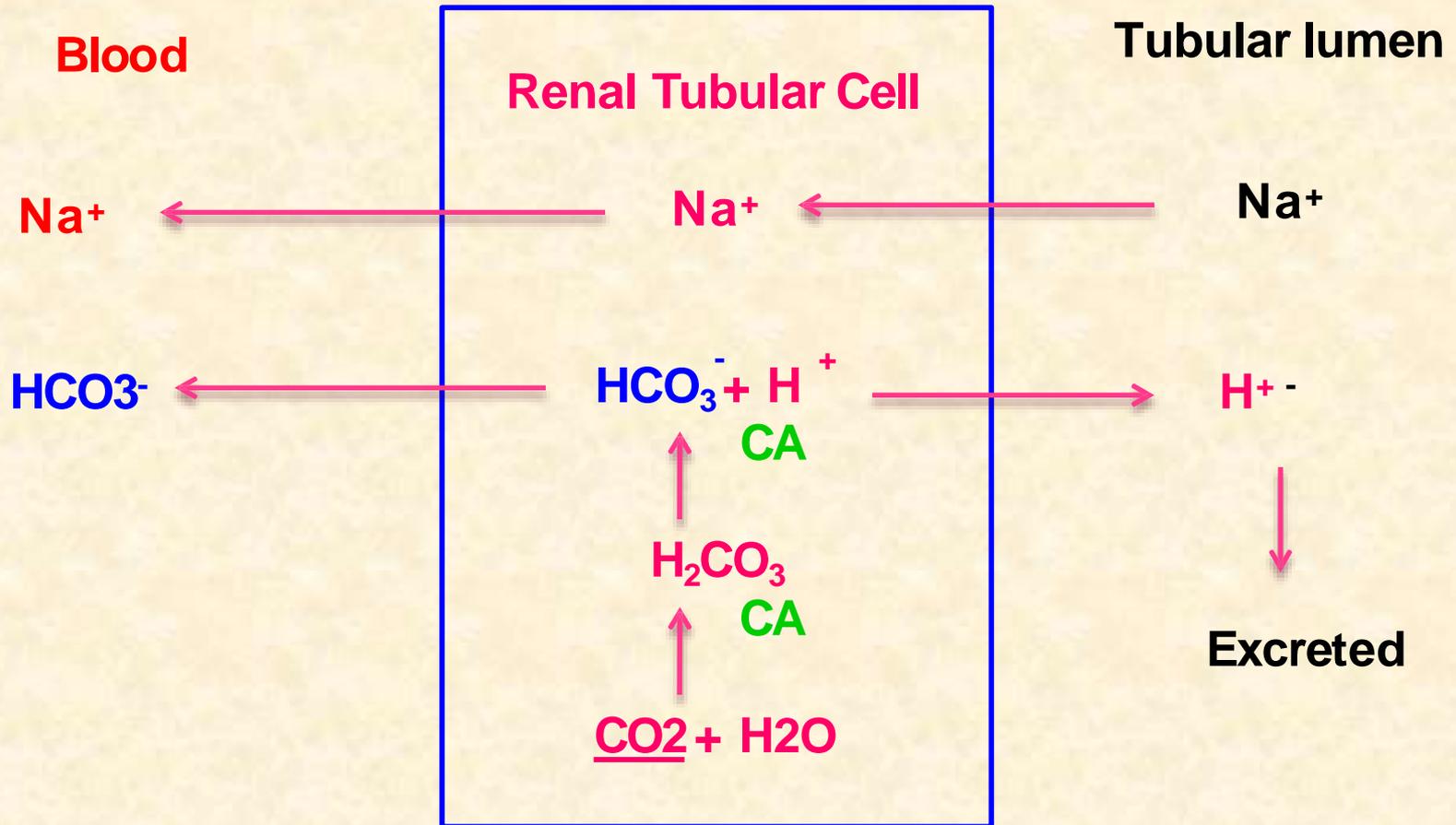
Renal mechanism for pH regulation

- The kidneys plays an important role in the regulation of pH through:
 - 1-Excretion of H⁺ ions
 - 2-Reabsorption of Bicarbonate
 - 3-Excretion of titratable acid
 - 4-Excretion of ammonium ions

Excretion of H⁺ ions

- Kidney is the only route through which the H⁺ can be eliminated from the body.
- H⁺ excretion occurs in the proximal convoluted tubules & is coupled with generation of HCO₃⁻.
- Carbonic anhydrase catalyses the production of carbonic acid (H₂CO₃) from CO₂ & H₂O in renal tubular cells.
- H₂CO₃ then dissociates to H⁺ & HCO₃⁻
- H⁺ ions are secreted into tubular lumen in exchange for Na⁺
- Na⁺ in association with HCO₃⁻ is reabsorbed into blood

Excretion of H⁺ ions

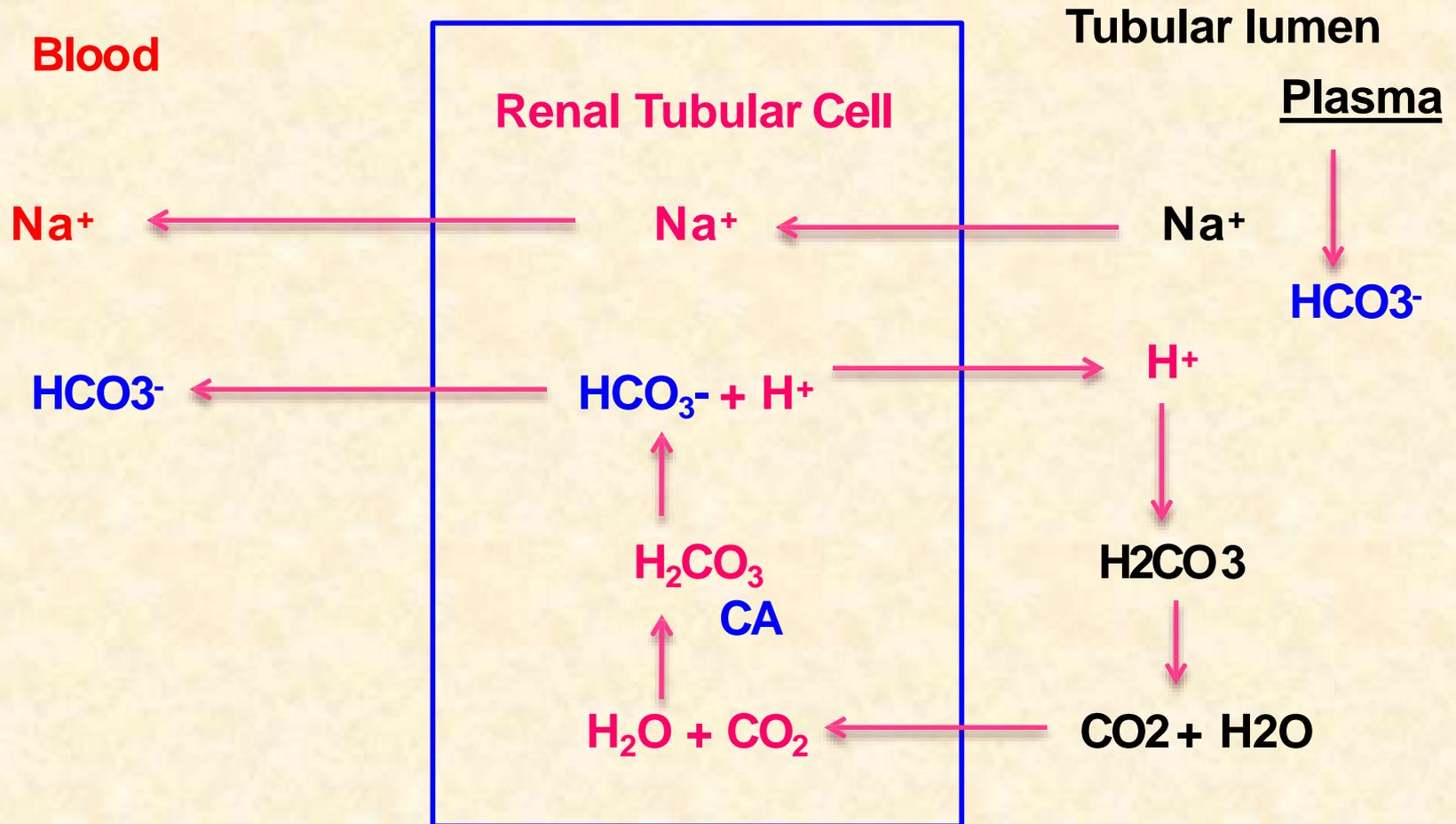


Reabsorption of Bicarbonate

- This mechanism is responsible to conserve blood HCO_3^- , with simultaneous excretion of H^+ ions.
- Bicarbonate freely diffuses from plasma into tubular lumen.
- HCO_3^- combines with H^+ , secreted by tubular cells, to form H_2CO_3 .
- H_2CO_3 is then cleaved to form CO_2 and H_2O .
- As the CO_2 concentration builds up in the lumen, it diffuses into the tubular cells along the concentration gradient.

- In the tubular cell, CO_2 again combines with H_2O to form H_2CO_3 which then dissociates into H^+ & HCO_3^-
- The H^+ is secreted into the lumen in exchange for Na^+ .
- The HCO_3^- is reabsorbed into plasma in association with Na^+ .
- Reabsorption of HCO_3^- is a cyclic process without net excretion of H^+ or generation of new HCO_3^-

Reabsorption of bicarbonate

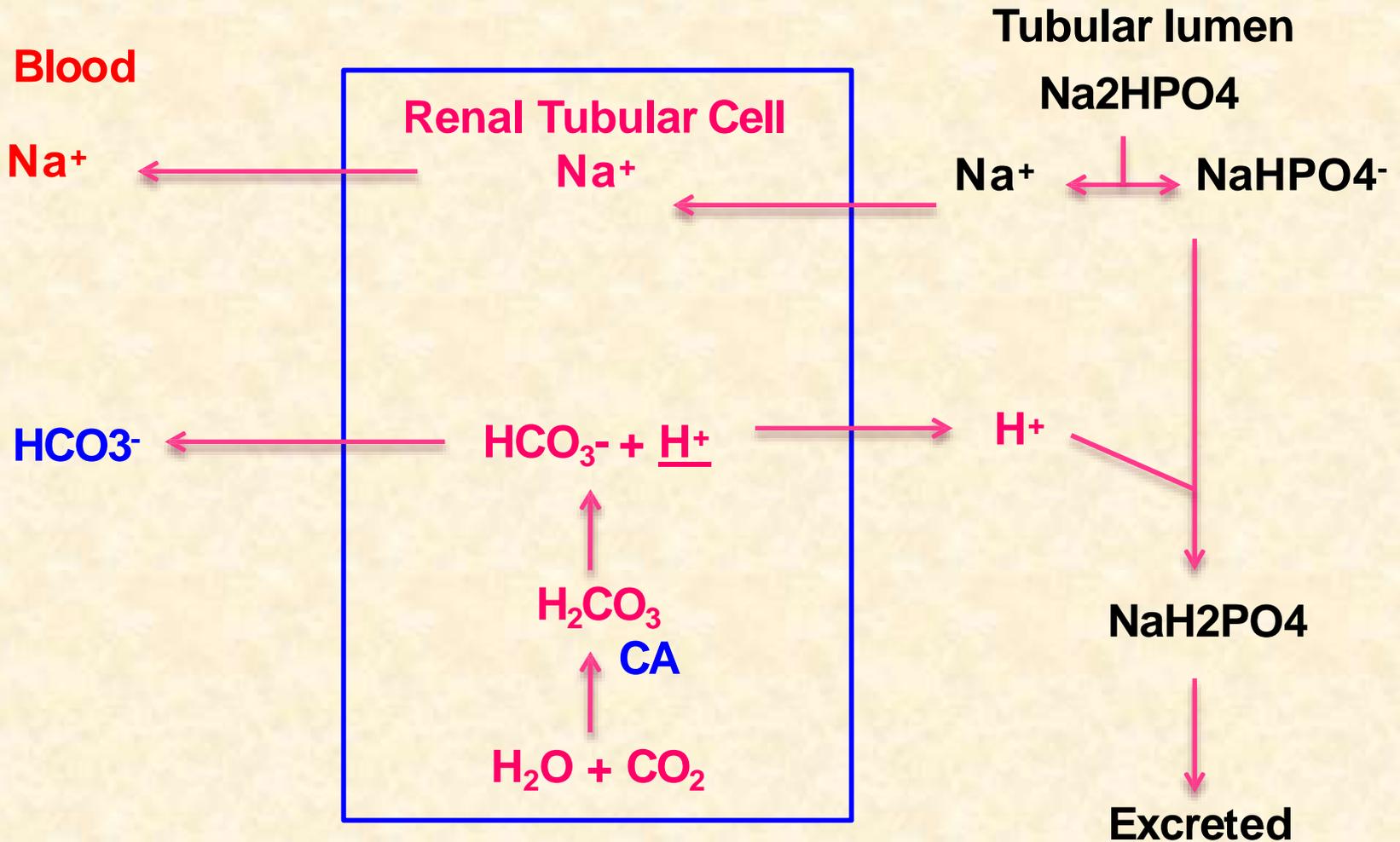


Excretion of titratable acid

- Titratable acidity is a measure of acid excreted into urine by the kidney.
- Titratable acidity refers to the number of milliliters of N/10 NaOH required to titrate 1 liter of urine to pH 7.4.
- Titratable acidity reflects the H⁺ ions excreted into urine.

- **H⁺ ions are secreted into the tubular lumen in exchange for Na⁺ ion.**
- **This Na⁺ is obtained from the base, disodium hydrogen phosphate (Na₂HPO₄).**
- **This combines with H⁺ to produce the acid, sodium dihydrogen phosphate (NaH₂PO₄), in which form the major quantity of titratable acid in urine is present.**
- **Tubular fluid moves down the renal tubules, more and more H⁺ ions are added, resulting in the acidification of urine. Causes a fall in the pH of urine as low as 4.5.**

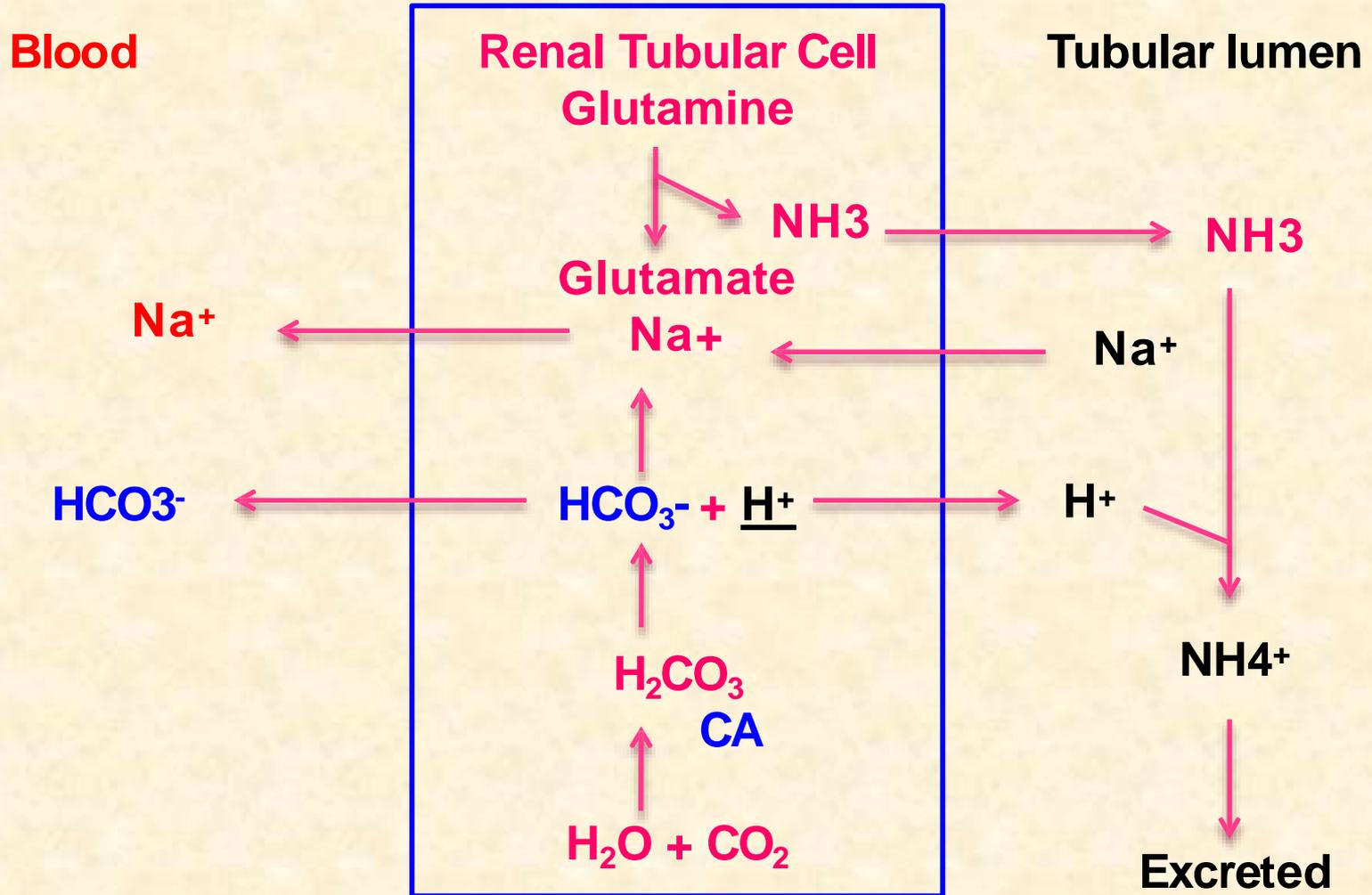
Excretion of titratable acid



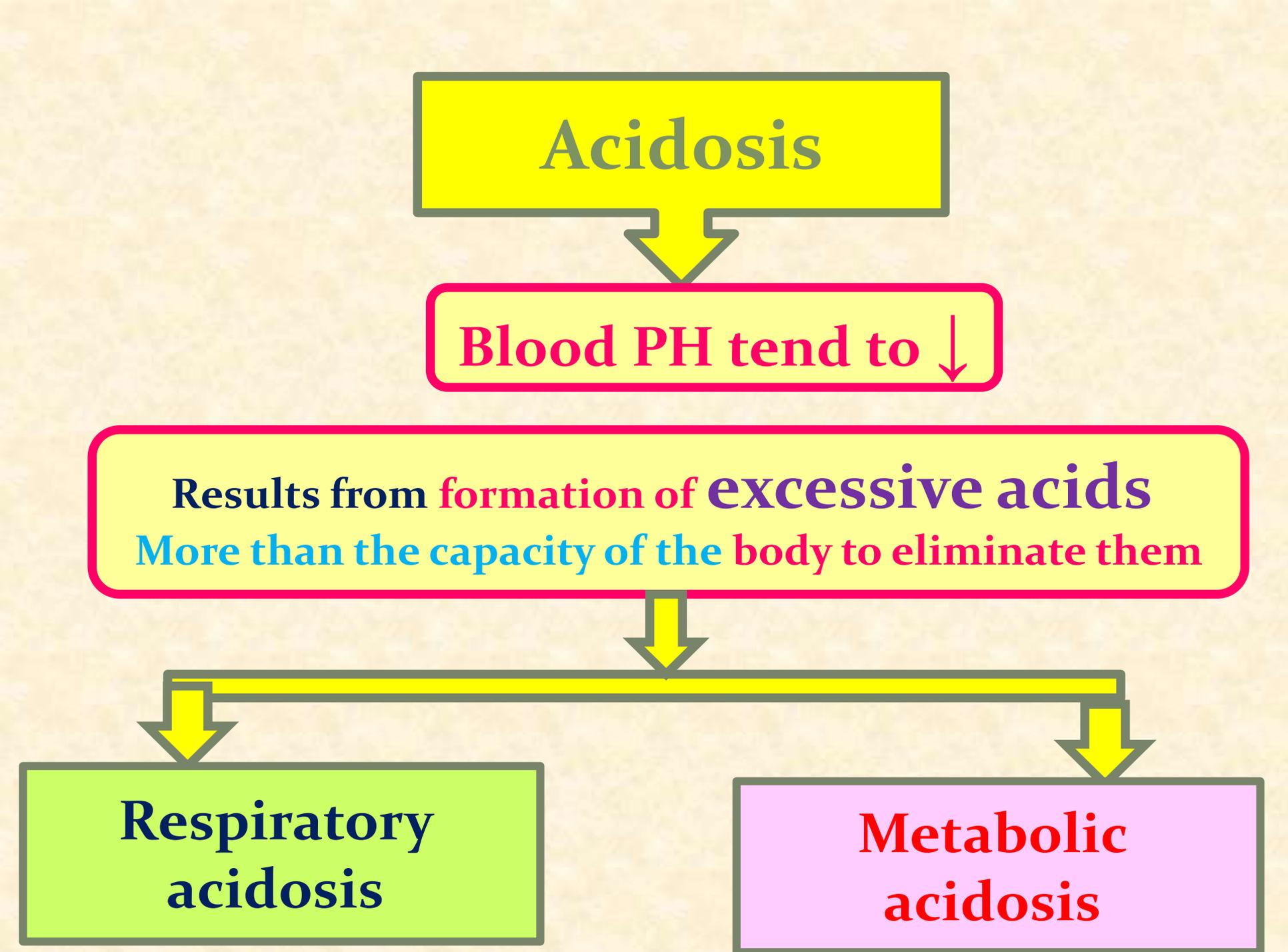
Excretion of ammonium ions

- The H^+ ion combines with NH_3 to form ammonium ion (NH_4^+).
- The renal tubular cells deaminate glutamine to glutamate and NH_3 by the action of enzyme glutaminase.
- The liberated NH_3 diffuses into the tubular lumen where it combines with H^+ to form NH_4^+ .
- Ammonium ions cannot diffuse back into tubular cells and excreted into urine.

Excretion of ammonium ions



Acidosis



```
graph TD; A[Acidosis] --> B[Blood PH tend to ↓]; B --> C[Results from formation of excessive acids  
More than the capacity of the body to eliminate them]; C --> D[Respiratory acidosis]; C --> E[Metabolic acidosis];
```

The diagram is a vertical flowchart. At the top is a yellow rectangular box with a black border containing the word 'Acidosis'. A yellow arrow points down from this box to a pink rounded rectangular box with a black border containing the text 'Blood PH tend to ↓'. Below this is a larger yellow rounded rectangular box with a black border containing the text 'Results from formation of excessive acids' and 'More than the capacity of the body to eliminate them'. A yellow arrow points down from this box to a horizontal yellow line. From the left end of this line, a yellow arrow points down to a light green rectangular box with a black border containing the text 'Respiratory acidosis'. From the right end of the horizontal line, a yellow arrow points down to a light purple rectangular box with a black border containing the text 'Metabolic acidosis'.

Blood PH tend to ↓

Results from **formation of excessive acids**
More than the capacity of the body to eliminate them

**Respiratory
acidosis**

**Metabolic
acidosis**

Respiratory acidosis

↑CO₂ (CO₂ RETENTION) due to

- Bronchial asthma
- Chronic bronchitis
- Emphysema
- Pneumonia
- Respiratory centre inhibition
- Asphexia

↑CO₂ → ↑ blood H₂CO₃

Respiratory acidosis

$\uparrow \text{CO}_2$ \rightarrow \uparrow blood H_2CO_3
 \searrow HCO_3^- not changed
 $\rightarrow \downarrow \text{HCO}_3^-/\text{H}_2\text{CO}_3$ (N=20:1)
 $\rightarrow \downarrow$ blood PH

(Uncompensated respiratory acidosis [acidemia])

How to compensate?

Kidney reabsorbs more HCO_3^-

Till normal $\text{HCO}_3^-/\text{H}_2\text{CO}_3$ (20:1)

\rightarrow PH reach 7.4

Metabolic acidosis

↑ acids or ↓ bases (HCO_3^-) in blood

↙ ↓ blood HCO_3^-

↘ blood H_2CO_3 not changed

→ ↓ $\text{HCO}_3^-/\text{H}_2\text{CO}_3$ (N=20:1)

→ ↓ blood PH

(Uncompensated metabolic acidosis [acidemia])

How to compensate?

↓ PH → ++ chemoreceptors in respiratory centre → hyperventilation → loss of CO_2 → ↓ H_2CO_3

Till normal $\text{HCO}_3^-/\text{H}_2\text{CO}_3$ (20:1)

→ PH reach 7.4 (Compensated metabolic acidosis)

Causes of Metabolic acidosis

1- ↑ blood acids

↑ production

- ❑ ↑ lactic acid in muscular exercise
- ❑ ↑ ketone bodies in Ketosis due to Diabetes mellitus
- ❑ ↑ acids from metabolism of different food stuffs (diet) as pyruvic , lactic, phosphoric and nucleic acids.

↓ excretion

- ❑ failure of excretion by the kidney in chronic renal failure

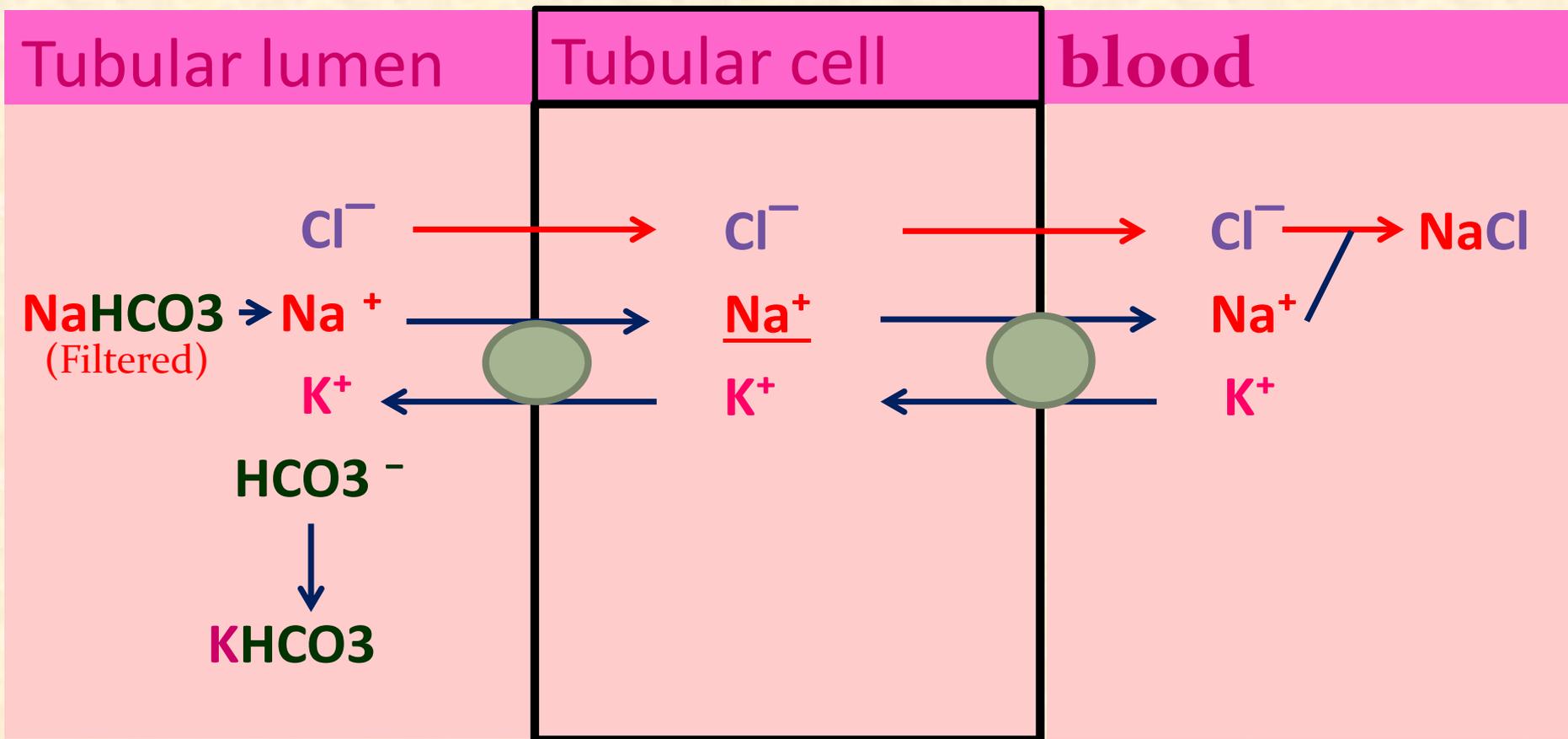
Causes of Metabolic acidosis

1- ↑ base loss

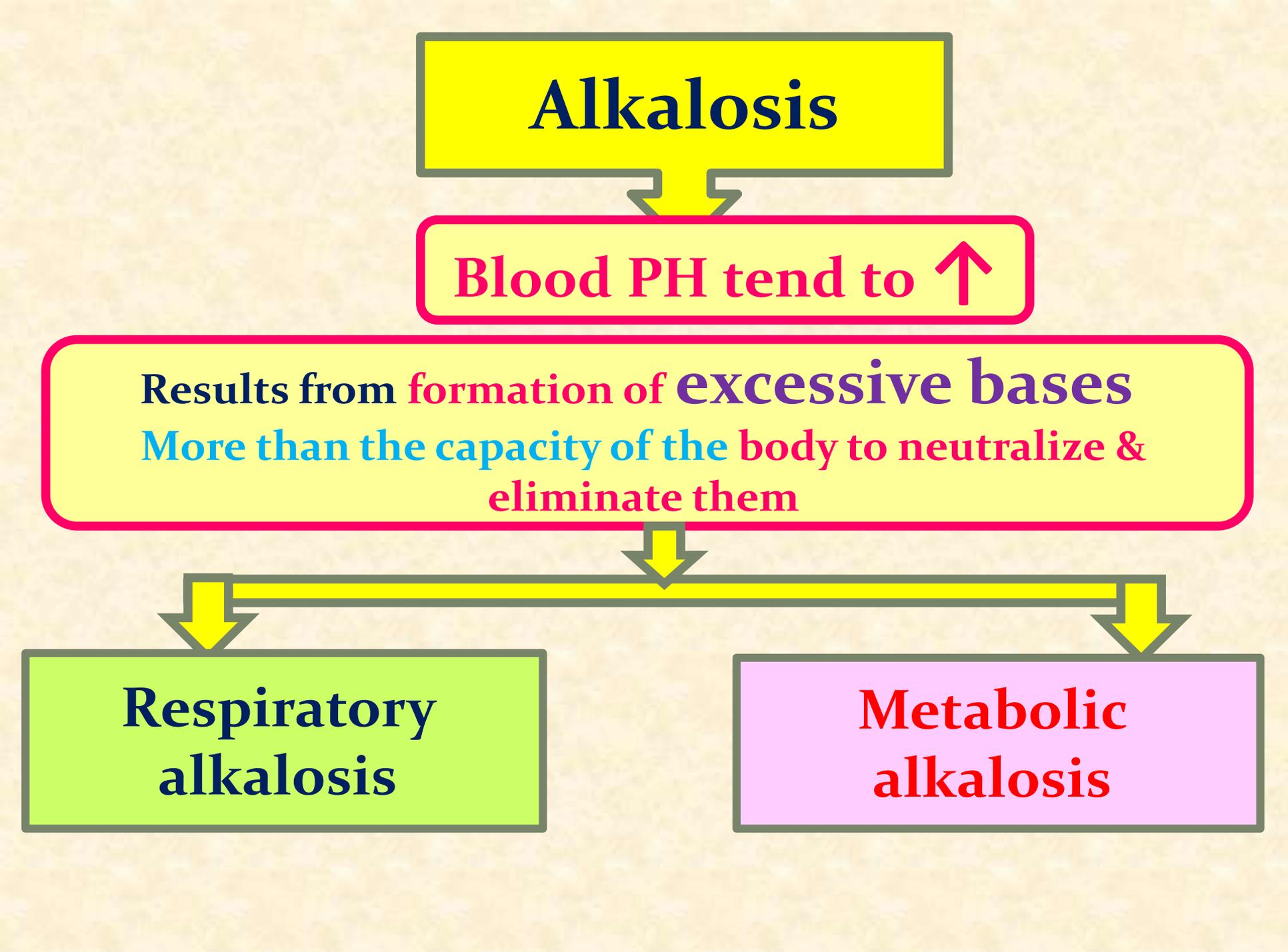
- ❑ Diarrhea: Intestinal juices are alkaline being rich in Na^+ & K^+ bicarbonate
 - ❑ Vomiting: due to low intestinal obstruction
 - ❑ Hyperkalemia:
 - * ↑ renal tubular reabsorption of Na^+ in exchange with K^+
→ stop of Na^+ / H^+ exchange
 - * Na^+ reabsorption will be in the form of NaCl not NaHCO_3 > HCO_3^- will be excreted in the form of KHCO_3 in urine.
 HCO_3^- loss in urine → metabolic acidosis (Alkaline urine)
↑ Cl in blood → hyperchloremic acidosis (Acidic blood)
- The alkaline urine & acidic blood is called paradoxical acidosis

Causes of Metabolic acidosis

1- ↑ blood acids



Alkalosis



```
graph TD; A[Alkalosis] --> B[Blood PH tend to ↑]; B --> C[Results from formation of excessive bases  
More than the capacity of the body to neutralize & eliminate them]; C --> D[Respiratory alkalosis]; C --> E[Metabolic alkalosis];
```

The diagram is a flowchart illustrating the concept of alkalosis. It starts with a yellow box labeled 'Alkalosis'. An arrow points down to a pink box stating 'Blood PH tend to ↑'. Another arrow points down to a larger yellow box with a pink border explaining that alkalosis results from the formation of excessive bases, exceeding the body's capacity to neutralize and eliminate them. From this box, two arrows branch out to two final boxes: a green box for 'Respiratory alkalosis' and a purple box for 'Metabolic alkalosis'.

Blood PH tend to ↑

Results from **formation of excessive bases**
More than the capacity of the body to neutralize & eliminate them

Respiratory alkalosis

Metabolic alkalosis

Respiratory alkalosis

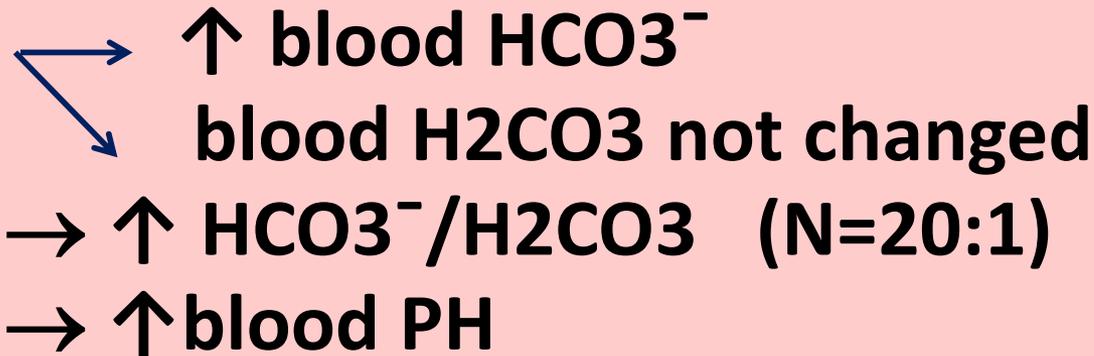
↑ **CO₂ loss** due to

- fever
- encephalitis
- high altitude
- late stages of salicylate poisoning
- hysterical hyperventilation

↓ **CO₂** → ↓ **blood H₂CO₃**

Metabolic alkalosis

↑ bases or ↓ acids in blood



(Uncompensated metabolic alkalosis [acidemia])

How to compensate?

↑ PH → - - - chemoreceptors in respiratory centre → hypoventilation → CO_2 retention → ↑ H_2CO_3

Till normal $\text{HCO}_3^-/\text{H}_2\text{CO}_3$ (20:1)

→ PH reach 7.4 (Compensated metabolic alkalosis)

Causes of Metabolic alkalosis

1- ↑ absorption of bases

- ❑ Intake of high vegetable and fruit diet: They contain Bicarbonate salts and citrate salts. Citrate salts will be transformed into bicarbonate salts by krebs cycle
- ❑ Intake of drugs containing bicarbonate & citrate salts (drugs used for treatment of hyperacidity & peptic ulcer)

Causes of Metabolic alkalosis

2- ↑ loss of acids

- ❑ Prolonged suction of gastric juice
 - ❑ Vomiting due to high intestinal obstruction
 - ❑ Hypokalemia:
 - * ↓ renal tubular reabsorption of Na^+ in exchange with K^+
→ instead there is Na^+ / H^+ exchange
 - * Na^+ reabsorption will be in the form of NaHCO_3 not NaCl →
 - # Cl^- loss in urine in the form of NH_4Cl → hypochloremia and acidic urine

 - ↑ NaHCO_3 in blood → alkalosis (alkaline blood)
- The acidic urine & alkaline blood is called paradoxical alkalosis
- ❑ Cushing syndrome: → Na & water retention & K excretion → hypokalemia