ACID - BASE BALANCE
And
it's Disorders

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pH

- pH = -log (H+)
- Acidity depends on Hydrogen ion concentration.
- Lower the pH = Higher Hydrogen
- Higher the pH = Lower Hydrogen.
- Normal pH of plasma = 7.38 to 7.42
- At the pH of 7.4 = 40 nanomoles/litre.

ACID

- **Release hydrogen ions** in solutions.
- Donate protons.
- Strong acids donate Completely
  - HCL
- Weak acids dissociates incompletely.
  - H2CO3

Base

- **Accept Hydrogen ions**.
  - For example, HCO3-.
- Strong Base accept proton Completely .
  - E.g. NaOH
- Weak acids accept incompletely in solution.
  - E.g. NH3

❖ Dissociation Constant (Ka):

- Since the dissociation of an acid is a freely reversible reaction.
- At equilibrium the ratio between dissociated and undissociated particle is a constant.

$$(HA) \longrightarrow (H+) + (A-)$$

$$Ka = \frac{(H+)(A-)}{(HA)}$$

❖ Henderson-Hasselbalch equation:

$$pH = pKa + \log \frac{(Base)}{(Acid)}$$

Henderson-Hasselbalch equation Derivation

$$K_\mathrm{a} = \frac{[\mathrm{H}^+][\mathrm{A}^-]}{[\mathrm{HA}]}$$

$$\log_{10} K_\mathrm{a} = \log_{10}\left(\frac{[\mathrm{H}^+][\mathrm{A}^-]}{[\mathrm{HA}]}\right)$$

$$\log_{10} K_\mathrm{a} = \log_{10}[\mathrm{H}^+] + \log_{10}\left(\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}\right)$$

$$-\mathrm{p}K_\mathrm{a} = -\mathrm{pH} + \log_{10}\left(\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}\right)$$

$$\mathrm{pH} = \mathrm{p}K_\mathrm{a} + \log_{10}\left(\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}\right)$$

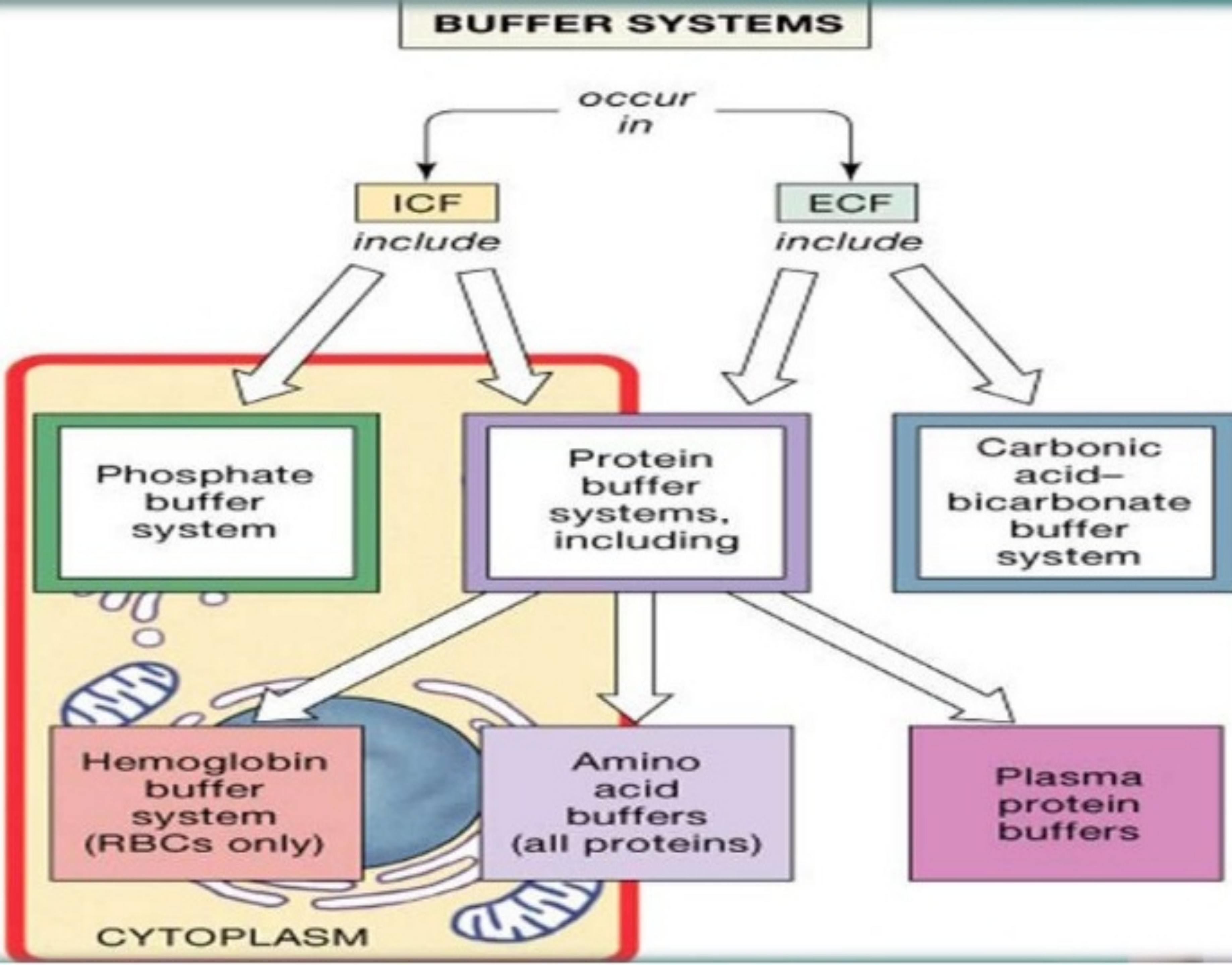
- When base (A-) & acid (HA) are same in concentration.
- pH = pKa.

Volatile & Non-Volatile acids

- During metabolism , acidic ions are produced.
- Added to the ECF.
- This has to be effectively buffered .

- Volatile acids
  - Carbonic acid.
  - Carbonic acid = Volatile = Eliminated as CO2 by Lung.

- Non Volatile
  - Lactate acid, Keto acids
  - Fixed acid are Buffered
  - Later , as H+ , they are excreted by kidney


BUFFER SYSTEMS
occur in
ICF
include
ECF
include
Phosphate buffer system
Protein buffer systems, including
Carbonic acid–bicarbonate buffer system
Hemoglobin buffer system (RBCs only)
Amino acid buffers (all proteins)
Plasma protein buffers
CYTOPLASM

Three Main Way of Acid-Base Balance

1. **Blood Buffer Mechanism**
    1. Bicarbonate buffer
    2. Phosphate buffer
    3. Protein buffer
    4. Haemoglobin buffer
2. **Respiratory Buffer Mechanism**
    1. Heamoglobin buffer
3. **Renal Buffer Mechanism**
    1. H+ excretion / titrable acid excretion
    2. HCO3- reabsorption
    3. Ammonium ions excretion

Blood Buffer

- ➢Buffers are solution which can resist changes in pH when acid or alkali is added.
- ➢Buffers are of two types:

1. Weak acids + Strong bases.
   - $H_2CO_3/NaHCO_3$ (Bicarbonate Buffer)
   - CH_3COOH/CH_3COONa(acetate Buffer)
2. Weak bases + Strong acids.

Distribution of Blood Buffers Systems

- Intra cellular buffers = 58%
  - 52% buffer activity is in tissue cells
  - 6% in RBCs.

- Extra cellular buffers = 42%
  - In plasma and extarcellular space,
  - 40% by Bicarbonate system
  - 1% by Proteins
  - 1% by Phosphate buffer system.

Blood Buffer System

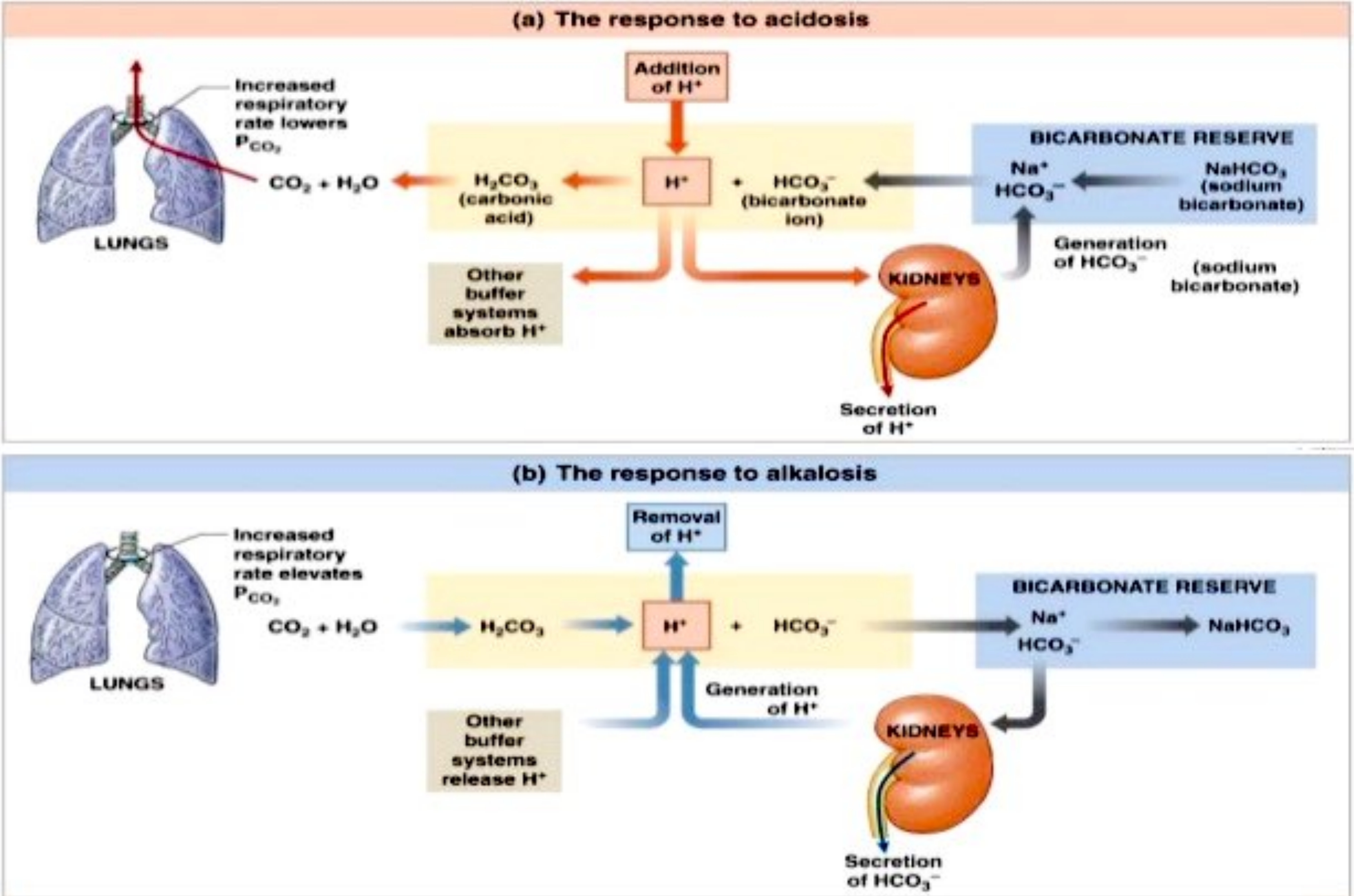
- Fast Acting
- Very Effective
- Not Permanent – Only Neutralize acid - bas

1. **Bicarbonate**
   – Most important buffer system in the body.
2. **Phosphate Buffer system**
   – It is mainly intracellular buffer.
   – Its concentration in plasma is very low.
   – $HPO_4^-/H_2PO_4^-$
3. **Proteins Buffer system**
   – Many proteins, not only albumin.
4. **Haemoglobin Buffer system**

Bicarbonate Buffer

- $H_2CO_3/NaHCO_3$ (Weak Acid / Strong Base)
- pK value = 6.1
- At pH = 7.4 ,
  - $H_2CO_3:NaHCO_3$ = 1:20
- High Concentration
- So Effective buffering capacity

Bicarbonate Blood Buffer



Phosphate Blood Buffer

- NaH_2PO_4 / Na_2HPO_4 (Strong Acid / Weak Base)
- pK value = 6.8
- At pH = 7.4 ,

– NaH_2PO_4 / Na_2HPO_4 = 1:4 Ratio

- Low Concentration
- Less effective buffering

Phosphate Blood Buffer

- When Acidosis
- Increase H+

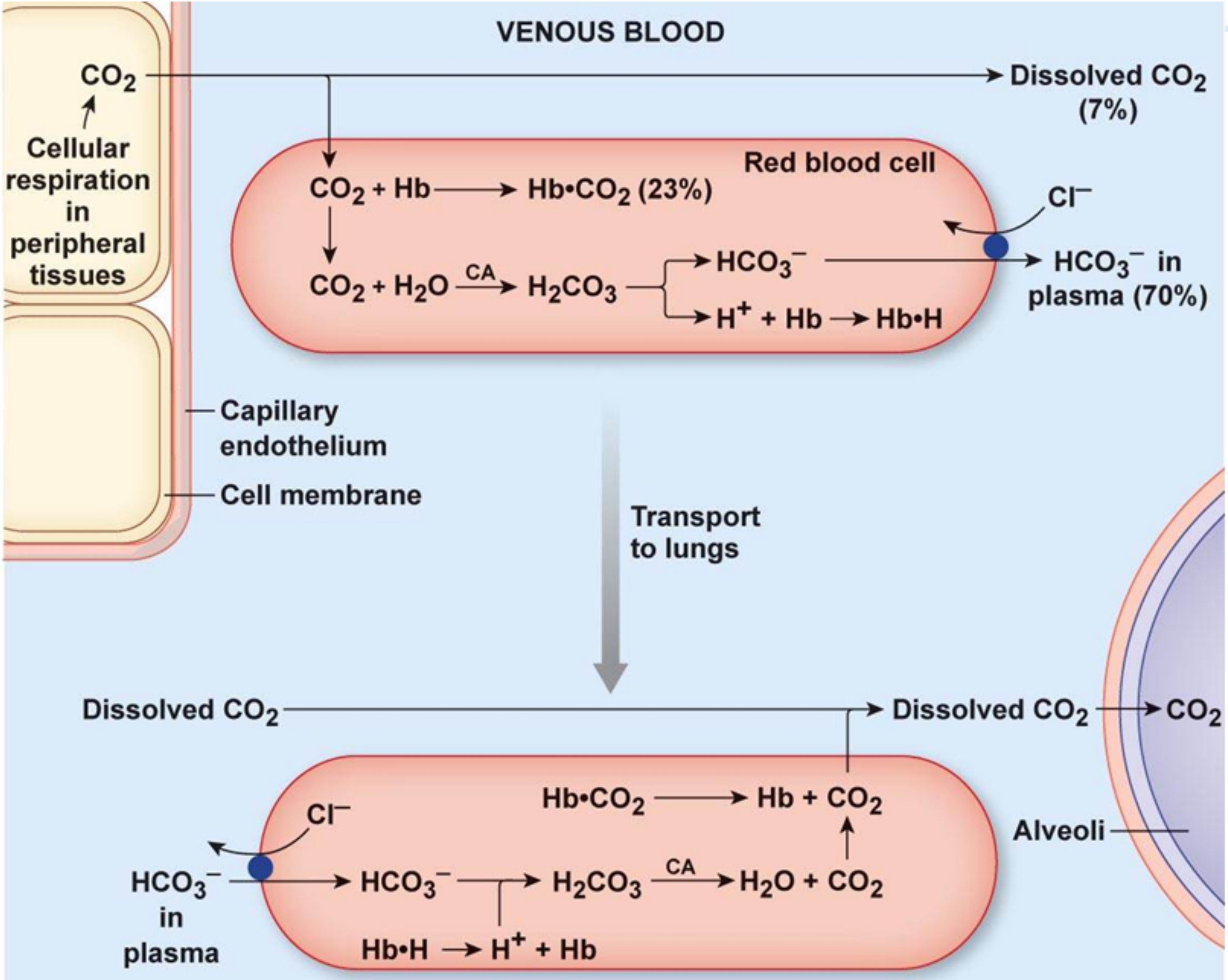
$$H_2PO_4 \Leftarrow H^+ + HPO_4$$

- When Alkalosis
- Decrease H+

$$H_2PO_4 \Rightarrow H^+ + HPO_4^{--};$$

Haemoglobin Buffer (Respiratory Buffer System)

- With carriage of O2 & CO2 transport, also play as buffer.
- Deoxygenated haemoglobin has the strongest affinity for both CO2 and H+
- Thus, buffering effect is strongest in the tissues.
- Carbon dioxide then either combines
  - Directly with haemoglobin = **Carbaminohaemoglobin.**
  - Water to form carbonic acid.

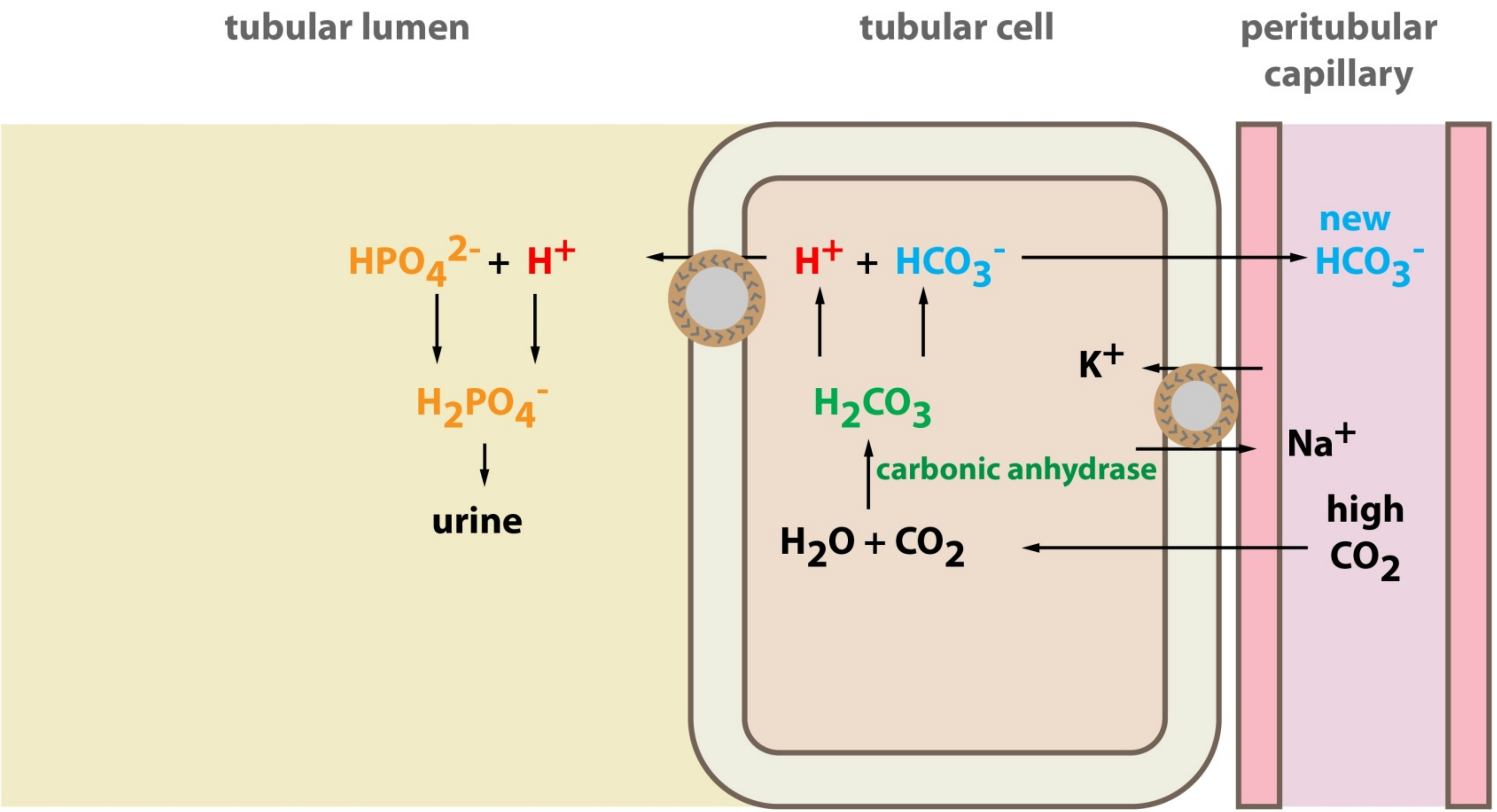


VENOUS BLOOD
CO2
Cellular respiration in peripheral tissues
Dissolved CO2 (7%)
Red blood cell
CO2 + Hb → Hb•CO2 (23%)
Cl⁻
CO2 + H2O CA → H2CO3
HCO3⁻
HCO3⁻ in plasma (70%)
H+ + Hb → Hb•H
Capillary endothelium
Cell membrane
Transport to lungs
Dissolved CO2
Dissolved CO2 → CO2
Hb•CO2 → Hb + CO2
Cl⁻
Alveoli
HCO3⁻ in plasma
HCO3⁻ → H2CO3 CA → H2O + CO2
Hb•H → H+ + Hb

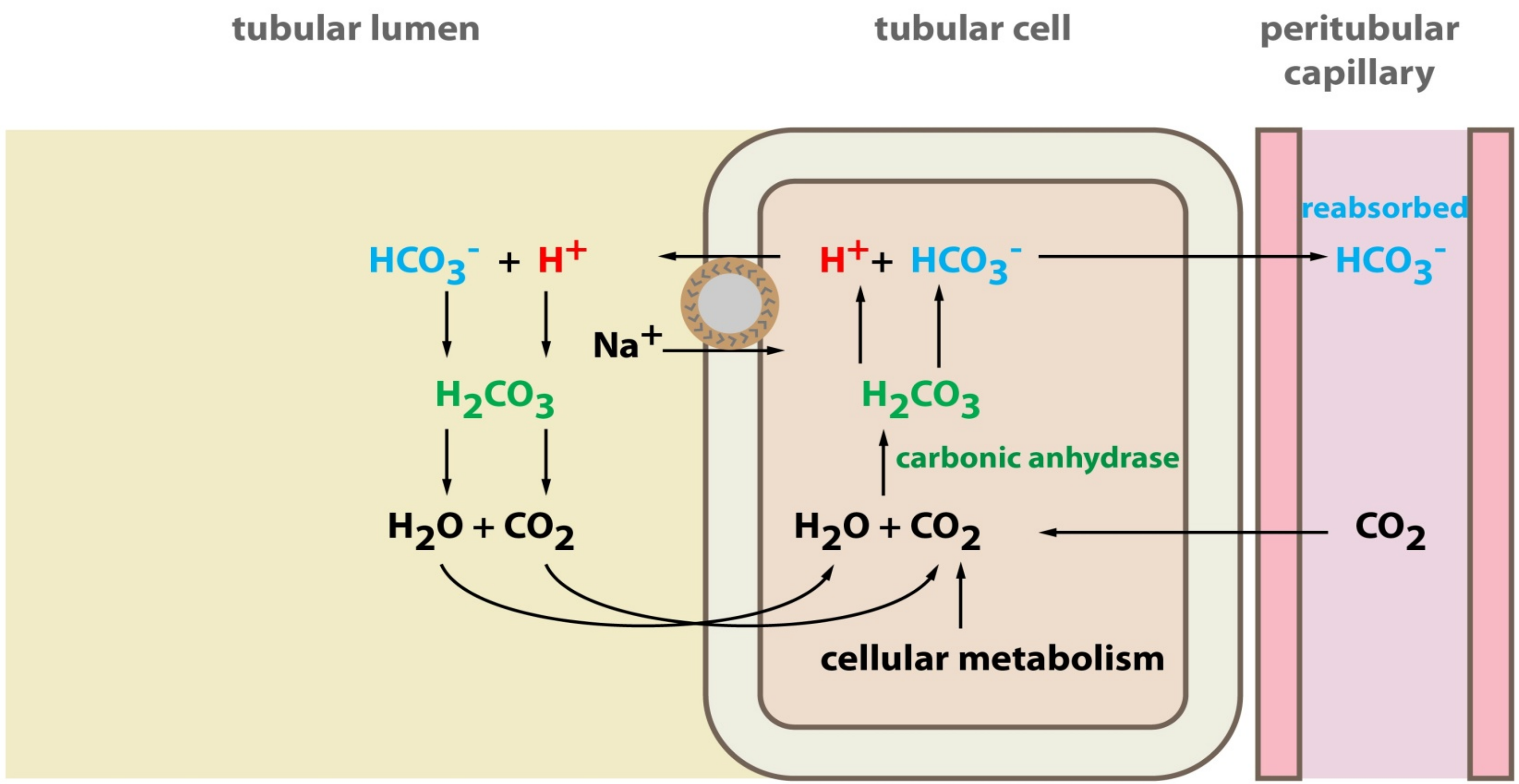
Renal Buffer System

- Long term balance
- Permanent Excretion of Acid-Base
- Through following mechanism
    1. H+ excretion / titrable acid excretion
    2. HCO_3^- reabsorption
    3. Ammonium ions excretion

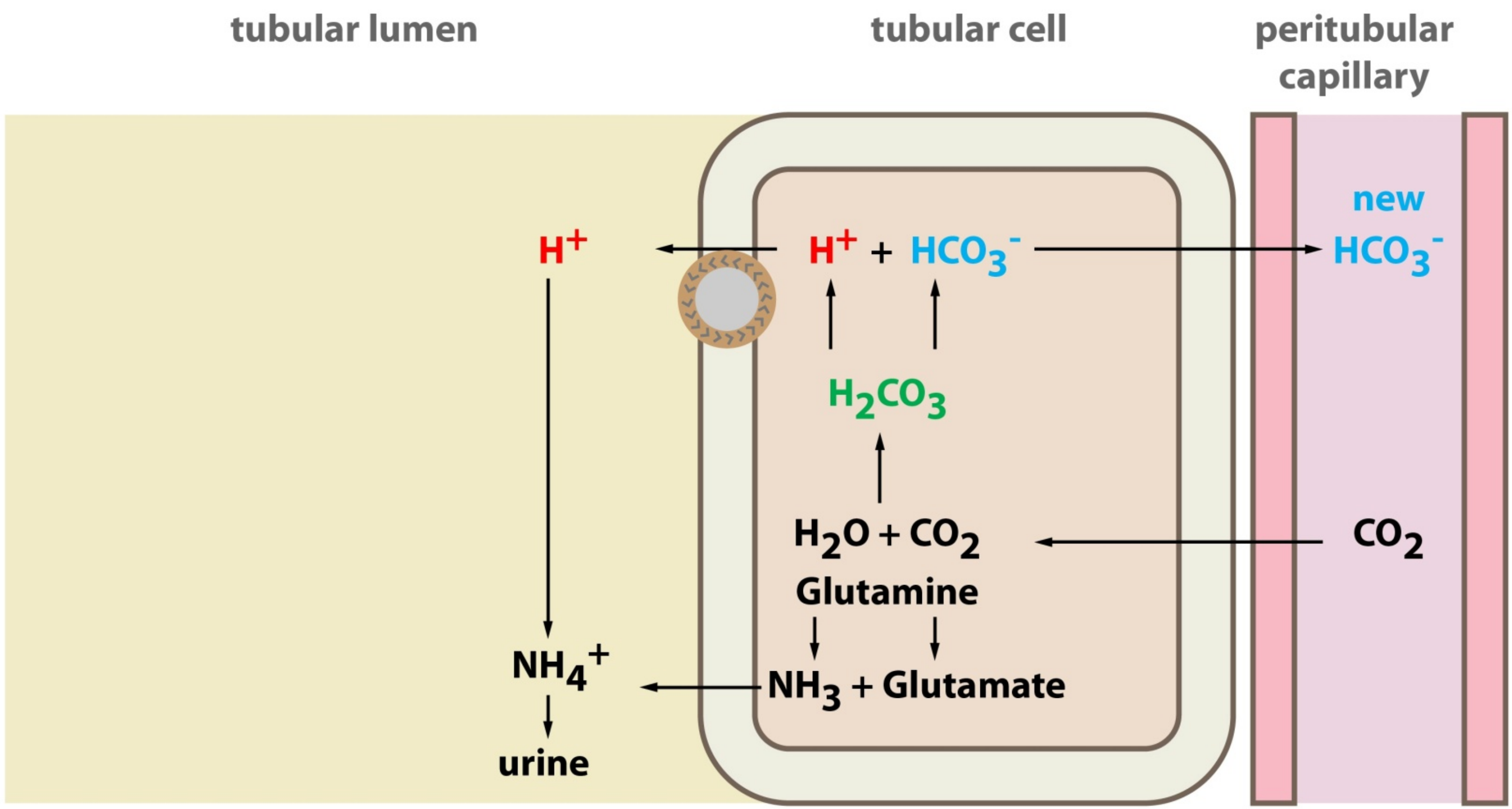
1. H+ Excretion



2. Reabsorption of HCO3-



3. Excretion Ammonium Ions



Arterial Blood Gas (ABG)Analysis

METHOD of Sample collection:-

- Arterial samples is collected from Radial or Femoral artery.
- Collected in Heparin containing vial
- And transported immediately to laboratory.
- Avoid expose to atmospheric air

Use of ABG :-

- detection of hypoxemia and hypercapnia
- management of respiratory failure
- care of the ventilated patient
- detection of abnormalities of acid – base balance

	Parameter of ABG	Physiological Range	Pathological
1	pH	7.35 to 7.45	< 7.35 = Acidosis >7.45 = Alkalosis
2	SpO2	90 – 100 %	
3	pO2	95 – 100 mmHg	< 80% = Hypoxia
4	pCO2	32 – 44 mmHg	< 32= Respiratory alkalosis > 44 = Respiratory acidosis
5	HCO3-	22 – 26 mmol/L	< 22 = Metabolic acidosis > 26 = Metabolic alkalosis
6	Base Excess	-2.0 to + 2.0 mmol/l	

		pH (7.35 – 7.45)	pO2 (95 - 100)	pCO2 (32 - 44)	HCO3- (22 - 26)
Metabolic acidosis	**Uncompensated**	Low	Normal	Normal	Low
	Partially compensated	Low	Normal	Low	Low
	Fully compensated	7.35	Normal	Low	Low
Metabolic Alkalosis	**Uncompensated**	High	Normal	Normal	High
	Partially compensated	High	Normal	High	High
	Fully compensated	7.45	Normal	High	High
Respiratory Acidosis	**Uncompensated**	Low	Normal/ Low	High	Normal
	Partially compensated	Low	Normal/Low	High	High
	Fully compensated	7.35	Normal/Low	High	High
Respiratory Alkalosis	**Uncompensated**	High	High / Normal /Low	Low	Normal
	Partially compensated	High	High / Normal /Low	Low	Low
	Fully compensated	7.45	High / Normal /Low	Low	Low

Respiratory Acidosis

➢ Due to retention of CO_2

<u>Causes</u>

- Brochopneumonia
- COPD
- Bronchial Asthma
- Morphine poisoning – Causing respiratory center depression
- Interstitial lung disease
- Central nervous system lesion

Respiratory Alkalosis

- ➢ Due to Excessive CO2 wash out

Causes :

- Hysterical attacks.
- Exercise
- High Grade fever.
- Hepatic coma.
- Thyrotoxicosis
- Pulmonary hypertention
- Pulmonary embolism

Metabolic Acidosis

- Due to Excessive H+ (organic acid) production
- Due to HCO- (base)Excretion

Causes

1. Hypovoluemic – Cardiogenic Shock
2. Ischemic disease
3. Diabetic Ketoacidosis
4. Starvation Ketoacidosis
5. Salicylate – Methanol Poisoning
6. Severe Diarrhea
7. Enterostomy drainage
8. Renal tubular acidosis
9. Adrenal Insufficiency

Metabolic Alkalosis

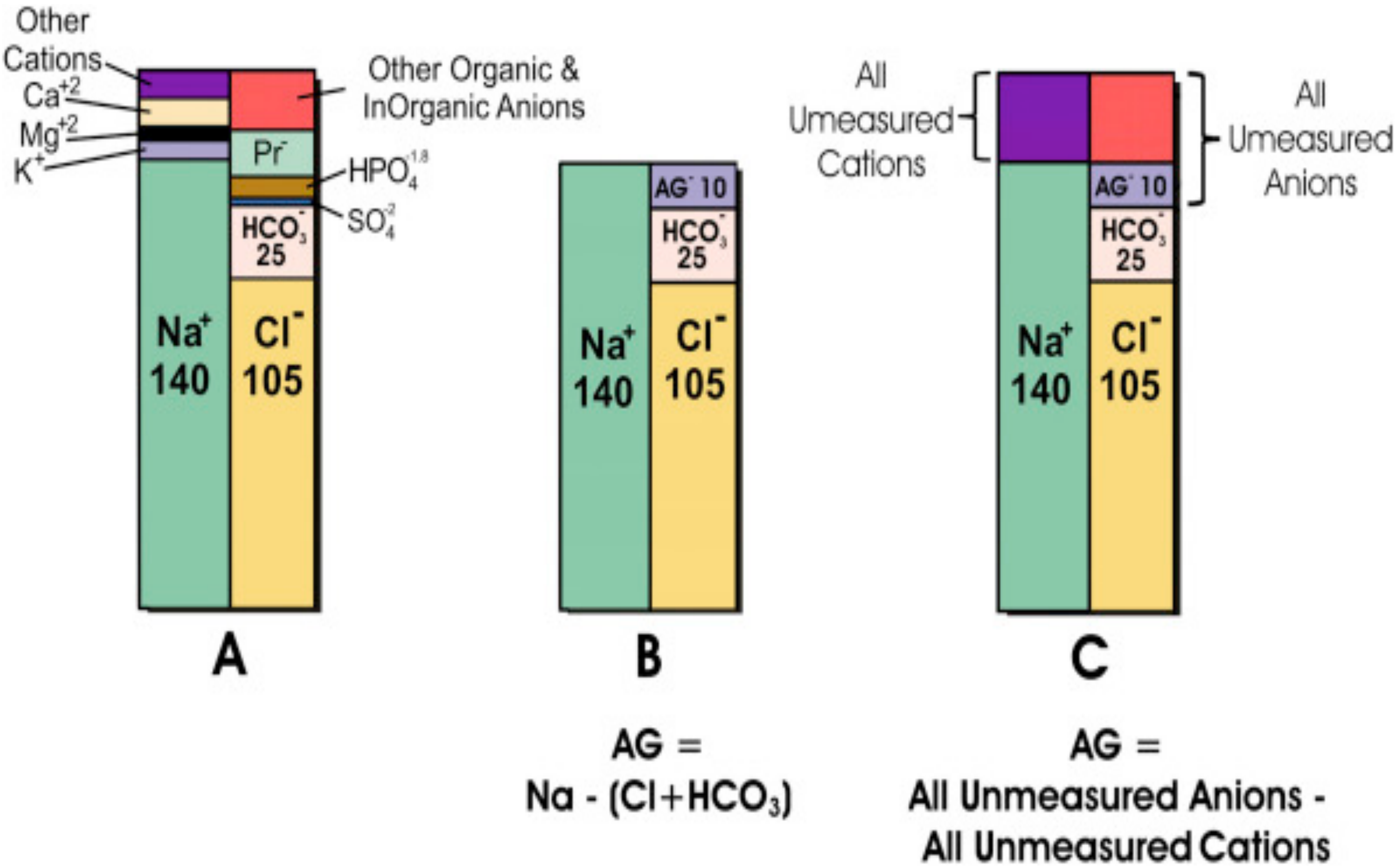
- Due to HCO- (base) production / Ingestion
- Due to Excessive H+ (organic acid) excretion

<u>Causes</u>

- Ingestion of alkali such as bicarbonate
- Prolonged vomiting
  - Pyloric stenosis
  - Intestinal obstruction
- Diuretic therapy
- Cushing syndrome
- Primary aldosteronism

Anion Gap

- Always in ECF
  - Conc. Of Cations = Conc. of Anions.
  - to maintain the electrical neutrality.
- Measurable Cation = Sodium + Potassium = 95% of Cations.
- Measurable Anion =Chloride + Bicarbonate = 86% of Anions.
- So, Difference between Measured Cations & Anions.
- **Unmeasured Anions = Anion Gap**
- Due to presence of protein anions , sulfate, phosphate & organic acids.



Anion Gap = [Na+] + [K+] – [Cl-] – [HCO3-]

= 10 to 20 mmol/L

Type of Anion Gap

1. High Anion Gap Acidosis.
2. Normal Anion Gap acidosis.
3. Low Anion Gap

High Anion Gap Acidosis

- Renal Failure
  - Decrease excretion of H^+
  - Decrease re-absorption of HCO_3^-
- Diabetic ketoacidosis
- Alcohol abuse
- Lactic acidosis
  - Tissue Hypoxia
  - Circulatory failure
- Methanol – Salicylate Poisoning

Normal Anion Gap Acidosis

- Severe Diarrhea
  - (Hyperchloremic Acidosis)
- Acetazolamide (Carbonic anhdrase inhibitor)
- Uretero-enteric fistula

Low Anion Gap

- Hypoalbunemia
- Multiple myeloma