ACID BASE BALANCE
OR
Homeostasis of Blood pH
OR
Regulation of Blood pH

Synopsis

- Introduction
- Sources of Acids and Bases in body
- What is Acid Base Balance?
- Mechanisms Regulating Blood pH.
- Significance of Maintaining Acid Base Balance
- Acid Base Imbalance and their conditions.
- Diagnostic Tests

Introduction

- Acid Base Balance is a **physiological and biochemical mechanism** associated to **body/blood pH**.

What Is pH?

- pH is a Hydrogen ion concentration.
- pH = - log $[H^+]$
- Different compartment of human body has specific pH.
- pH has role in Enzyme activity.

Why blood pH is Altered?

- **Addition** of various **acids or alkalies** by metabolic activities **alters body/blood pH.**

Sources and Types of Acids and Alkalies Added During Metabolic Life Processes

- Acids are H^+ donors.
- Bases are H^+ acceptors, or give up OH^- in solution.

Acid Production

Types of acids in the body

- **Volatile acid**
  - Can leave solution and enter the atmosphere (e.g. carbonic acid)
- **Fixed acids**
  - Acids that do not leave solution (e.g. sulfuric and phosphoric acids)
- **Organic acids**
  - Participants in or by-products of aerobic metabolism

Acids and Bases can be strong or weak:

- **A strong acid or base** is one that dissociates **completely** in a solution

  - HCl, $NaOH$, and H_2SO_4

- **A weak acid or base** is one that **dissociates partially i**n a solution

  -H_2CO_3, $C_3H_6O_3$, and CH_2O, Lactate.

- **Acidic Substances of body:**
  - –Carbonic acid(H_2CO_3)
  - –Phosphoric acid(H_3PO_4)
  - –Sulphuric acid (H_2SO_4)
- **Organic Acids:**
  - –Lactate, Acetoactate, Pyruvate
- **Alkaline Substances of body:**
  - –Citrate
  - –Bicarbonates.

What is Acid Base Balance?

Homeostatic Mechanisms That Regulate Blood/Body pH

- Acid Base balance is a **homeostatic mechanism**
- Carried out to **regulate the altered pH of blood** and other body compartments **to its normal constant range.**

- **Maintenance of Acid Base balance**
- **Is a prime requisite to maintain normal healthy and active life.**

Acid-Base Balance

- It is the regulation of **HYDROGEN** ions.

(*The <u>more</u> Hydrogen ions, the more acidic the solution and the <u>LOWER</u> the pH*)

– The acidity or alkalinity of a solution is measured as **pH**

Acid Base Balance Regulates pH

Why it is Very Essential To Regulate pH?

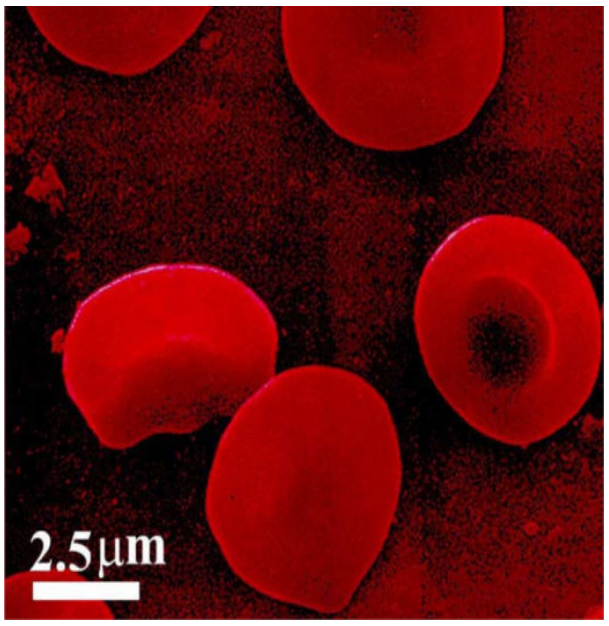
- pH of blood and other body compartments are precisely regulated.
- pH is always tried to be maintained to its normal constant range.

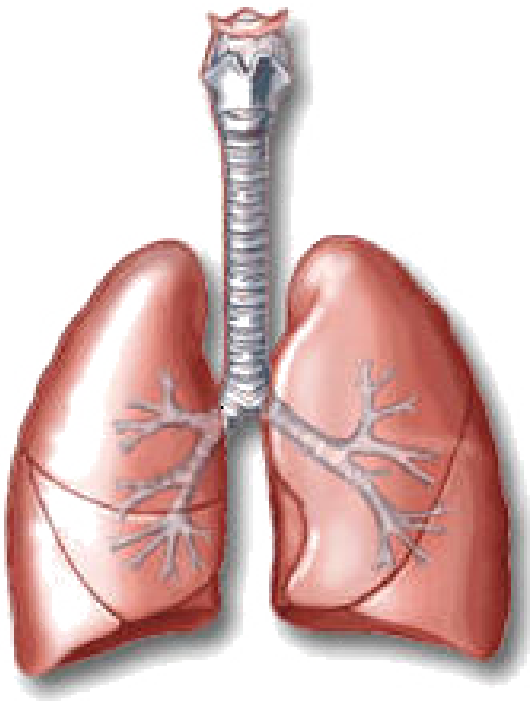
- Acid Base Balance maintains the blood pH at normal constant narrow range of 7.35-7.45.

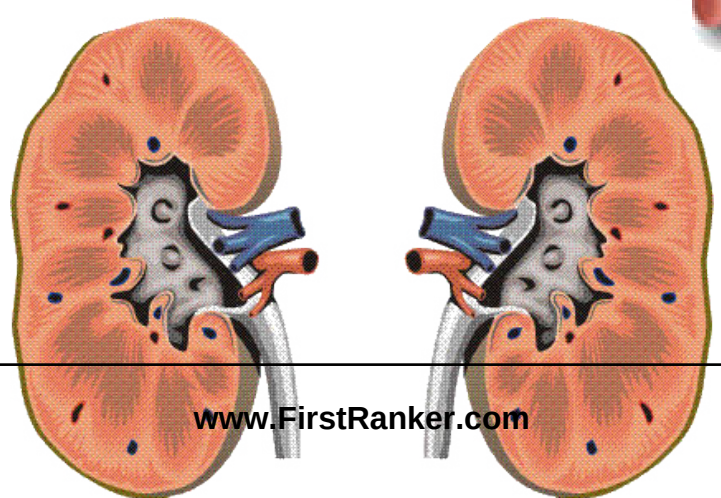
- pH of the medium directly affects the enzyme activities
- Optimum pH is an essential requisite for enzyme activities and normal metabolism.

- It is prerequisite for regulating blood/body pH:
  - **To maintain normal/optimal Enzyme activities**
  - **Normal metabolism**
  - **Normal Coordination**
  - **Normal Health**

Factors Regulating Acid Base Balance







Acid Base Balance is Regulated By

- **First Line of Defense**
  - ❖ **Blood Buffer System**
- **Second Line of Defense**
  - – **Respiratory Mechanism**
- **Third Line of Defense**
  - ➢ **Renal Mechanism**

1) Chemical Buffers

- React very rapidly (less than a second)

2) Respiratory Regulation

- Reacts rapidly (seconds to minutes)

3) Renal Regulation

- Reacts slowly (minutes to hours)

Role of Blood Buffer System

- First line of defense in mechanism of Acid Base Balance.
- **Acids (H^+) added are neutralized by** the **salt part of buffer.**

Extracellular Buffers

- **Bicarbonate Buffer**
  - –NaHCO3/H2CO3 (20:1 at 7.4 pH)
- **Phosphate Buffer**
  - –Na2HPO4/NaH2PO4 (4:1 at 7.4 pH)
- **Protein Buffer**
  - –Na-Protein/H-Protein

Intracellular Buffers

- **Bicarbonate Buffer**
  - –KHCO3/H2CO3
- **Phosphate Buffer**
  - –K2HPO4/KH2PO4
- **Protein Buffer**
  - –K-Hb/H-Protein

Mechanism Action of Buffer Systems

- **Buffers mixture of weak acids and its salts**
- **Resist change in pH of blood** when small amount of acids or alkalis added to the medium.

- **Buffers act quickly but not permanently**

Bicarbonate Buffer System
Respiratory Buffer System

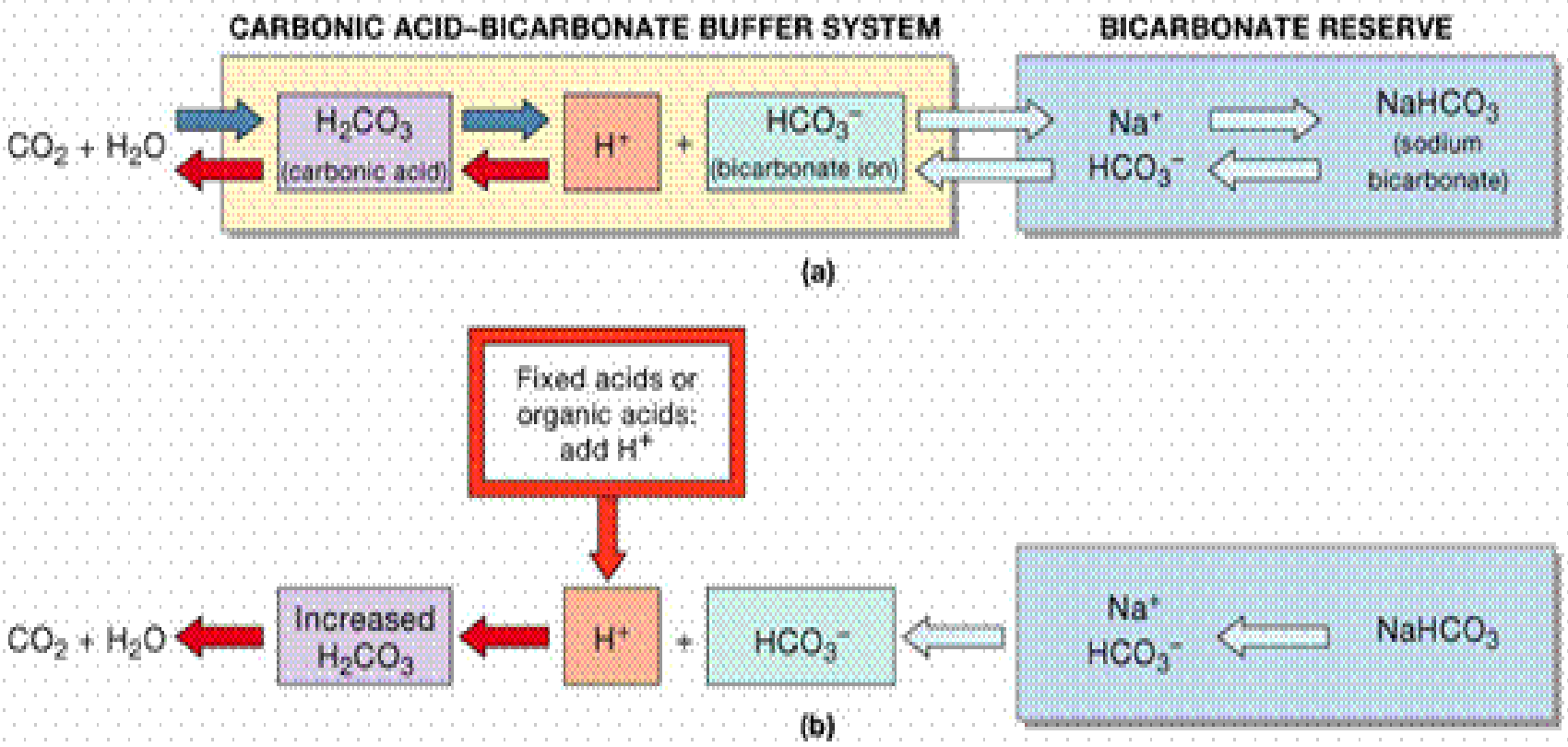
- **Acid - Base** balance is primarily concerned with Bicarbonate Buffer mechanism :
  - **H2CO3/ Hydrogen (H^+)**
  - **Bicarbonate (HCO_3^-) (Alkali Reserve)**

H^+ HCO_3^-

Bicarbonate Buffer

- **Bicarbonate Buffer- Chief Buffer system of Blood.**
- **NaHCO3** the salt part of buffer neutralizes the strong and non volatile acids added to blood.
- It constitutes **Alkali reserve(HCO_3^-)**

Bicarbonate Buffer System



Bicarbonate Buffer

- Sodium Bicarbonate ($NaHCO_3$) and carbonic acid (H_2CO_3)
- Maintain a 20:1 ratio : HCO_3^- : H_2CO_3

$HCl + NaHCO_3 \leftrightarrow H_2CO_3 + NaCl$

$NaOH + H_2CO_3 \leftrightarrow NaHCO_3 + H_2O$

- Action of Bicarbonate (NaHCO3) **converts strong** dissociable acid into **weak non dissociable acid** (H2CO3) and a neutral salt **without altering the pH.**

- **Weak acid H2CO3** formed during buffering action of **Bicarbonate buffer is then expired out by Lungs.**

- Thus **Bicarbonate buffer** is **connected to** the **respiratory system**

- **Bicarbonate buffer** is also **termed as Respiratory buffer.**

- **Alkali reserve** is represented by the **concentration of NaHCO3** in the blood.

- **Alkali reserve concentration(HCO_3^-)** determines the **strength of buffering action** towards added H^+ ions by acids.

- **More** the concentration of **Alkali reserve** ,**more is the buffering action** and vice a versa.

- The **blood buffers are effective** as long as
  - The **acid load added is not very high** and
  - The alkali **reserve ($HCO3^-$) is not exhausted.**

Phosphate Buffer/Urine Buffer

Na2HPO4/NaH2PO4 (4:1 at 7.4 pH)

- $H^+ + HPO_4^{2-} \leftrightarrow H_2PO4^-$
- $OH^- + H_2PO_4^- \leftrightarrow H_2O + H_2PO_4^{2-}$

Phosphate Buffer Mechanism

- When H+ ions added they are neutralized/fixed by Na2HPO4 (Alkaline Phosphate) and converted to **NaH2PO4 (Acid Phosphates).**
- **These acid phosphates then excreted out through kidneys** as **acidic urine**.

- Thus **Phosphate Buffer** is **connected to Excretory system .**

- **Phosphate Buffer also termed as Urine Buffer.**

- When an alkali enters it is buffered by the acid phosphate NaH2PO4 which converted to **Na2HPO4 alkaline phosphate.**
- Excreted in urine making it **alkaline urine.**

Protein Buffers

- Includes hemoglobin, work in blood.
- Carboxyl group gives up H^+
- Amino Group accepts H^+
- The **Imidazole group** of **Histidine** present in **Hb structure** has **buffering capacity.**

Role of Respiratory Mechanisms

- Respiratory system plays **second line of defense mechanism** of Acid Base Balance.
- Role of respiration in acid base balance is **short term regulatory process.**

- **H_2CO_3 formed from Bicarbonate Buffer, is exhaled out through respiratory system.**

- **Increased H_2CO_3 stimulates** the **respiratory centre** in Medulla Oblongata.

- This in turn **stimulates hyperventilation** which promptly removes H_2CO_3 from blood by expiration.

- Exhalation of H2CO3 is as carbon dioxide by activity of enzyme Carbonic Anhydrase of Lungs.

- $H^+ + HCO_3^- \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_20$

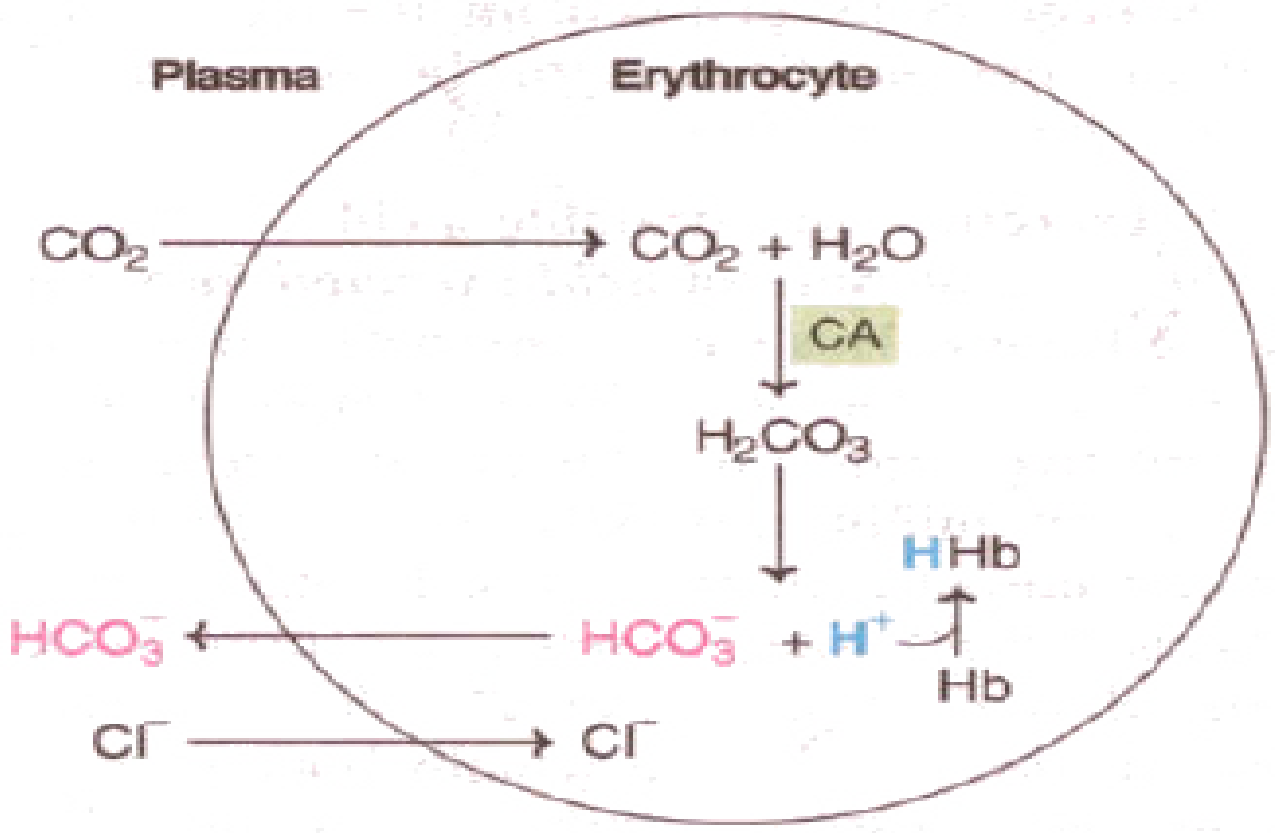
- Respiratory mechanism is powerful, but only works with **volatile acids.**
- Doesn’t affect **fixed acids** like lactic acid.

- **Blood pH can be adjusted through respiratory mechanism**
- **By changing rate and depth of breathing.**

- **Low H_2CO_3 concentration** in blood **depresses respiratory centre** ,causes **hypoventilation** i.e slow and shallow respiration.
- This **retains H_2CO_3** in blood.

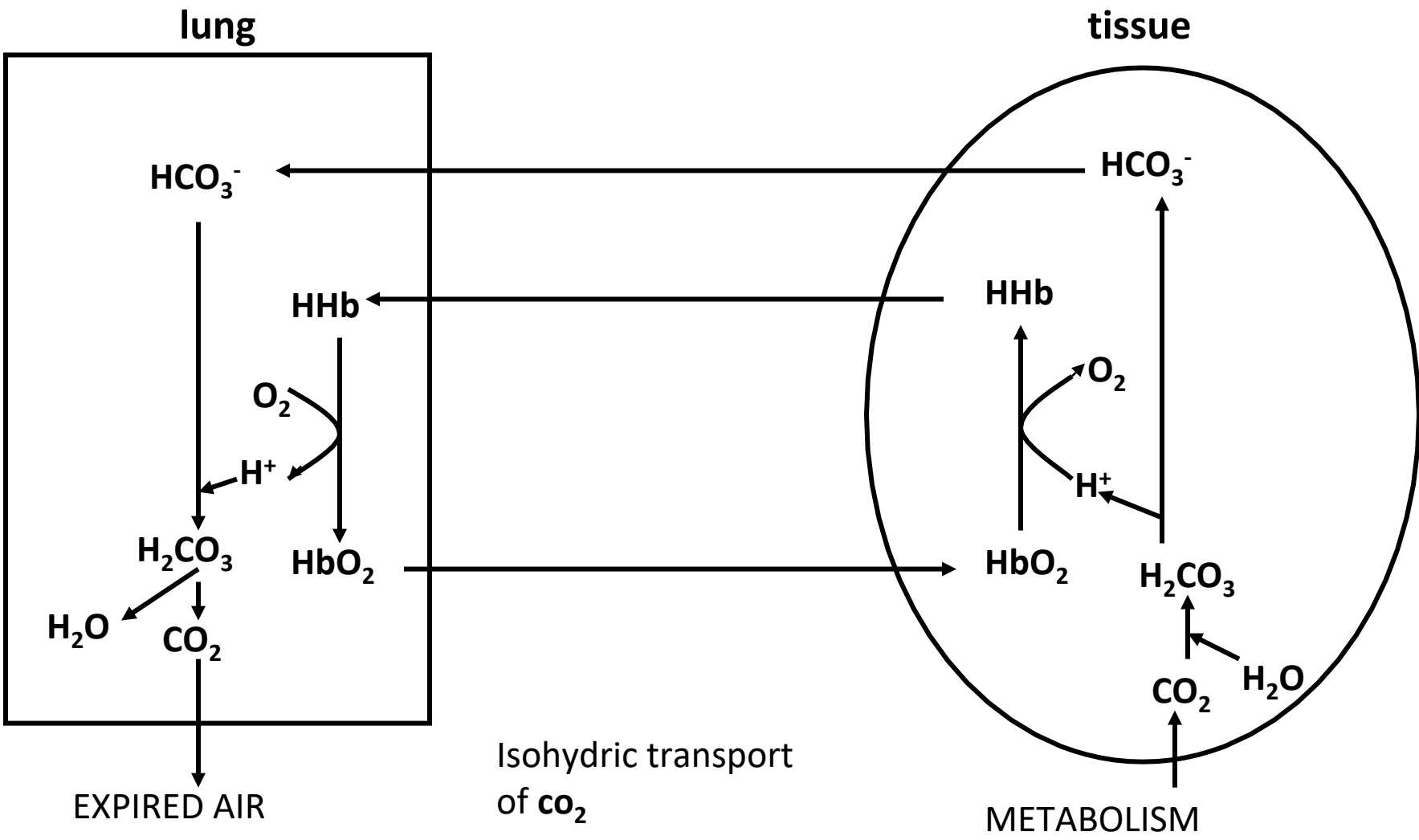
- If Nervous centre / Respiratory system fails.
- Acid Base Balance fails.

Generation of bicarbonate by RBC



LACK OF AEROBIC ACTIVITY,DIFFUSION OF CARBONDIOXIDE,H+ BUFFERED BY HHb.

Events in lungs and tissue



Role of Renal Mechanism

- **Renal mechanism** is the **third line of defense mechanism**.
- Role of renal mechanism is **long term regulatory process.**

- The **acid and alkaline phosphates** formed during **phosphate buffering** mechanism are filtered from blood and **excreted out through urine.**

- Thus the **phosphate buffer system is directly connected to renal mechanism.**

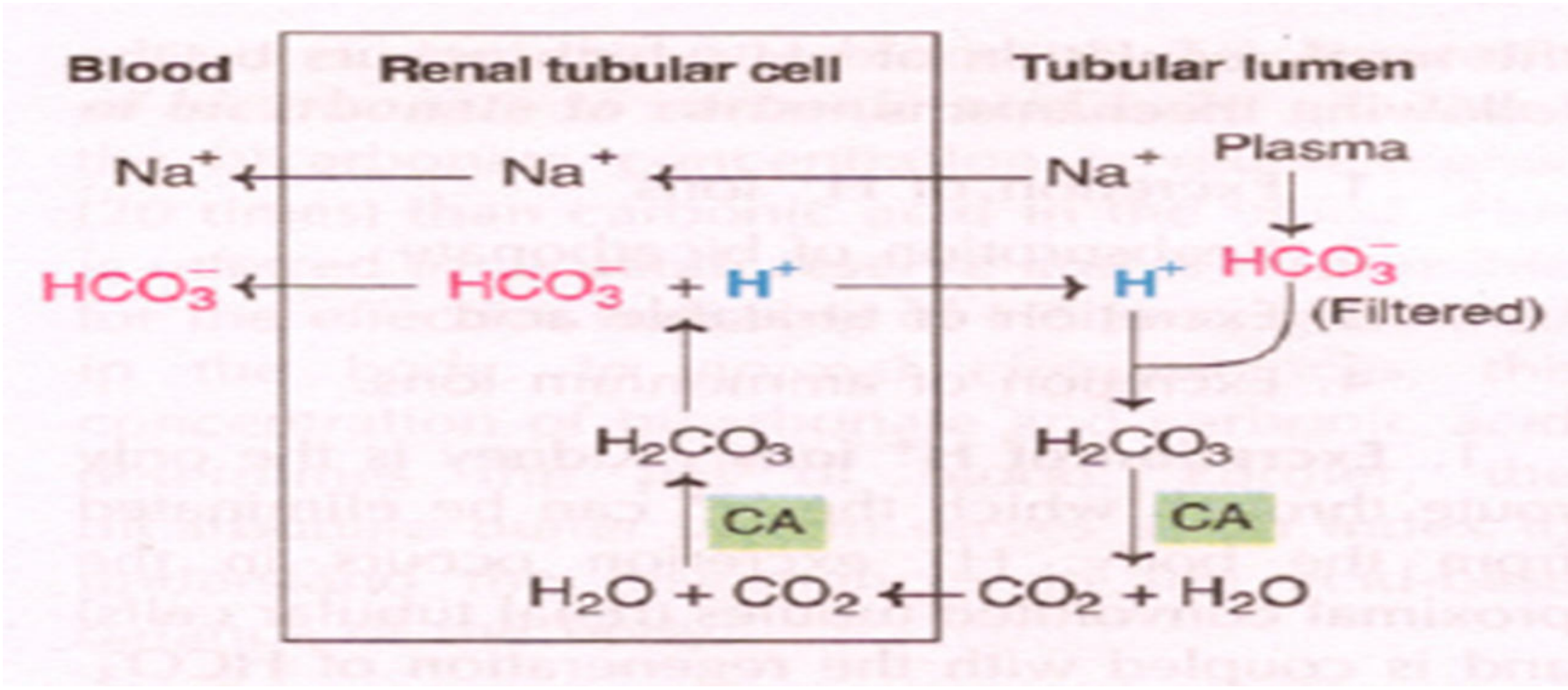
- Renal mechanism conserve and produce Bicarbonate ions (Alkali reserve).

- Renal Mechanism is the **most effective regulator** of blood pH.

- **If kidneys fail, pH balance fails.**

- **Renal System maintains Acid Base Balance through:**
  - **Reabsorption of Bicarbonate ($HCO3^-$) ions.**
  - **Excretion of H^+ ions**
  - **Excretion of titrable acids(Acid Phosphates)**
  - **Excretion of Ammonium ions (Glutaminase activity)**

REABSORPTION OF BICARBONATE

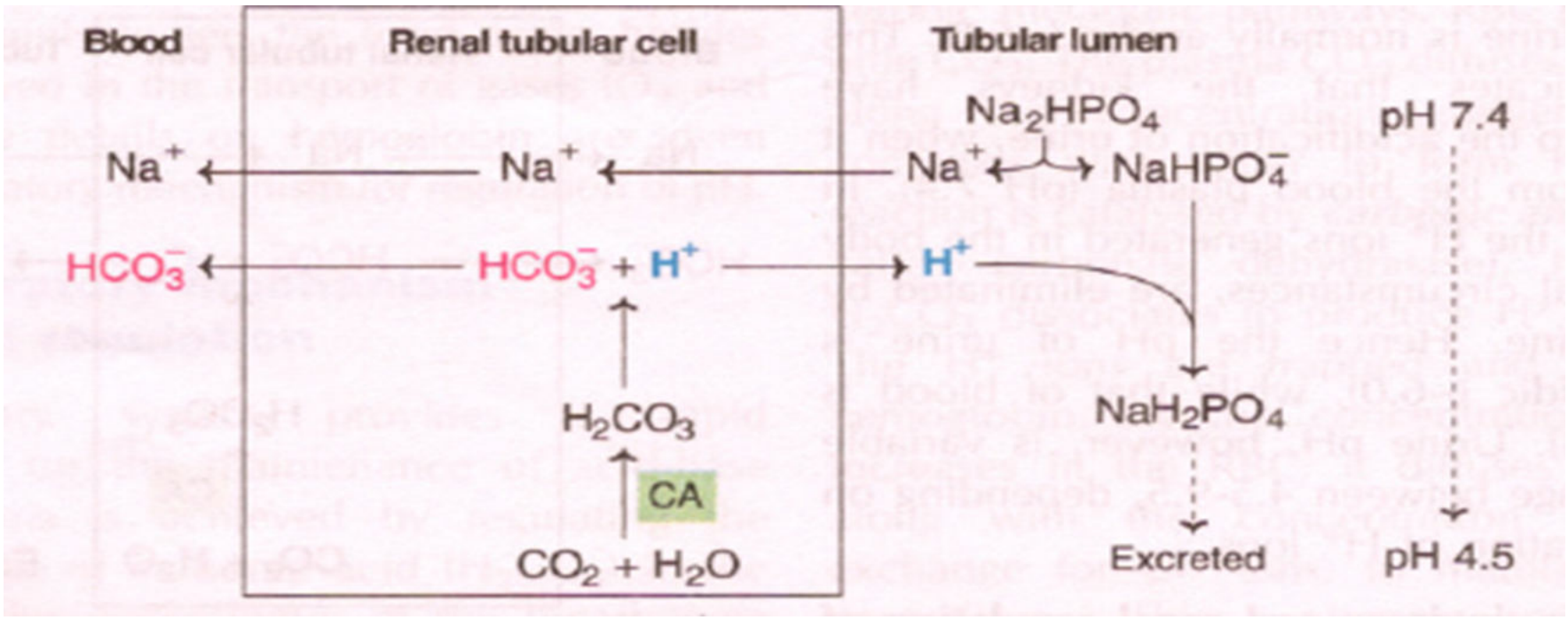


~Conservation of Bicarbonate

~Urine is free of HCO_3^-

~Simultaneous excretion of H^+

EXCRETION OF TITRABLE ACIDS

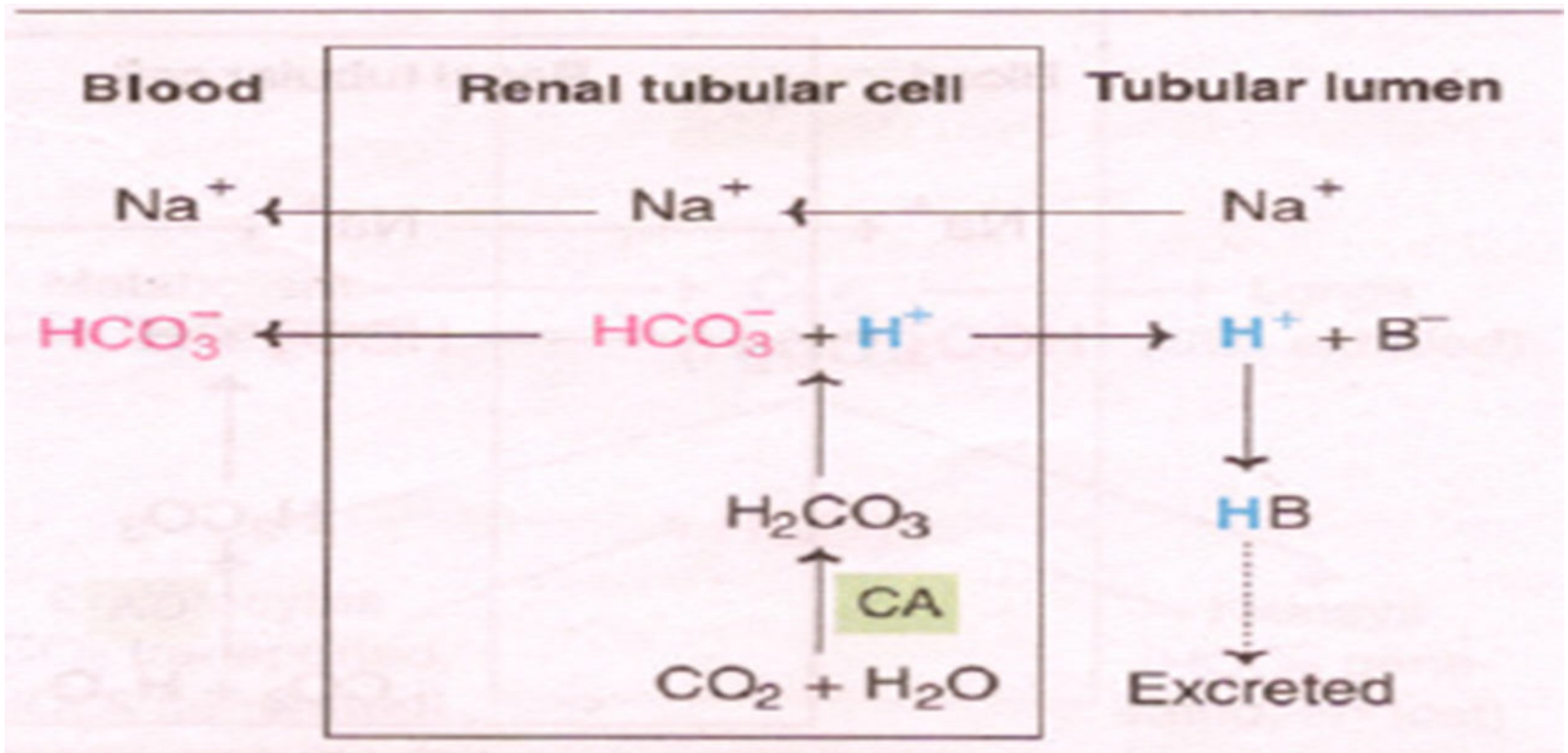


~measure of acid excreated by kidney

~no. of millilitres of N/10 NaOH required to titrate 1 litre of urine to pH 7.4

~role of phosphate buffer

Excretion Of H^+ ions



~Elimination of nonvolatile acid

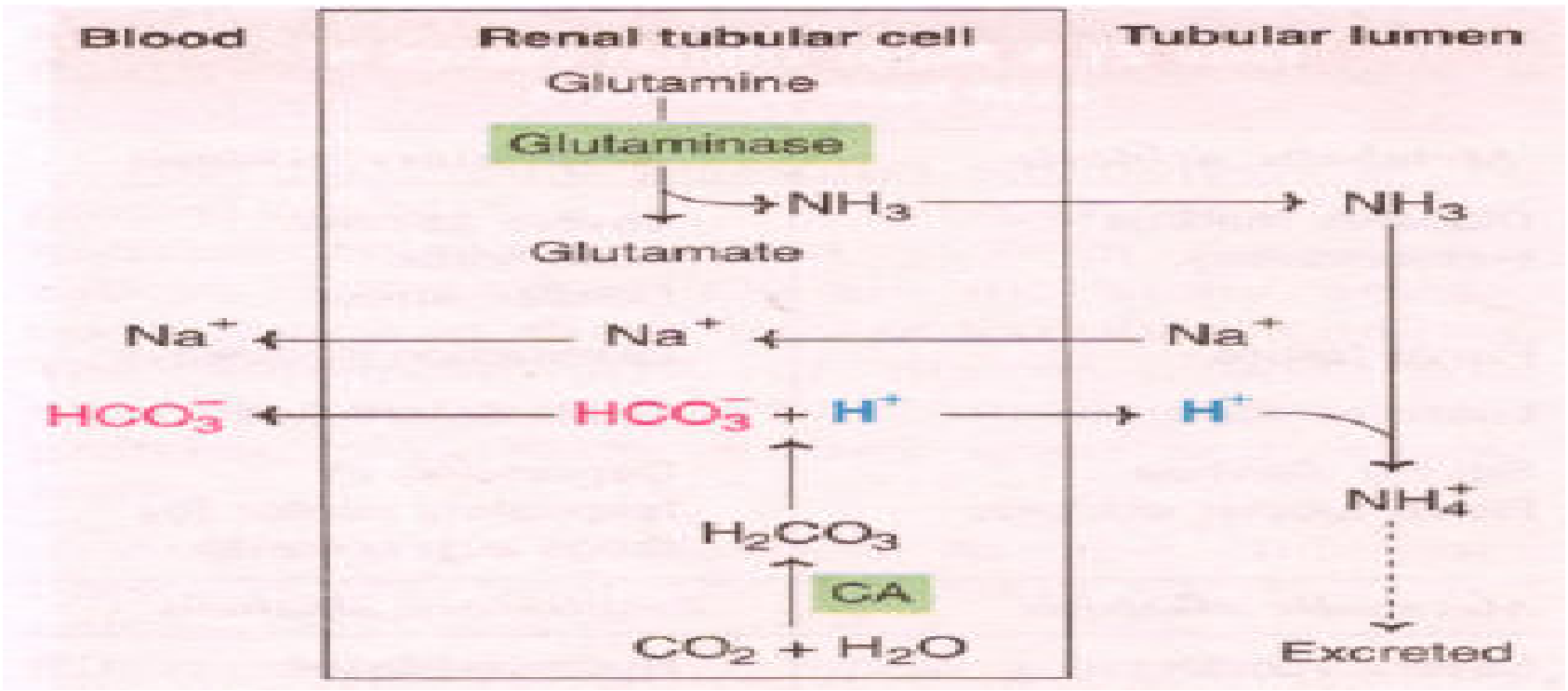
~Excretion of H+

~Occurs in PCT

~Regeneration of bicarbonate

~H+ combine with non carbonate base and excreated

EXCRETION OF AMMONIUM ION



NH3 is obtained from Deamination of Glutamine

NH_4^+ cant diffuse back

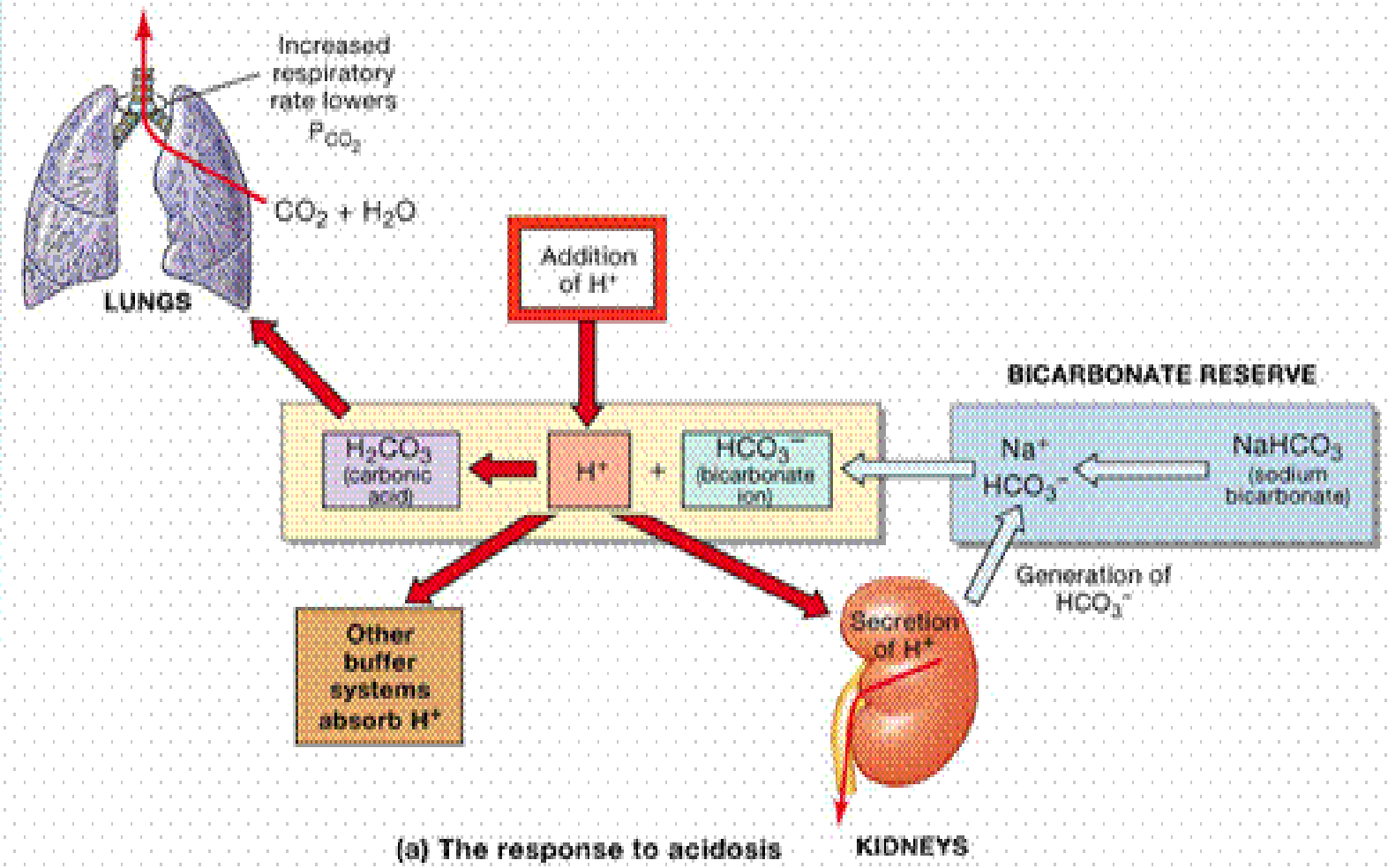
2/3 of body acid load liberated in the form of NH_4^+

Rates of correction

- Buffers function almost instantaneously
- Respiratory mechanisms take several minutes to hours
- Renal mechanisms may take several hours to days

Respiratory & Renal Regulation of pH

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$



(a) The response to acidosis

First line of defense against pH shift

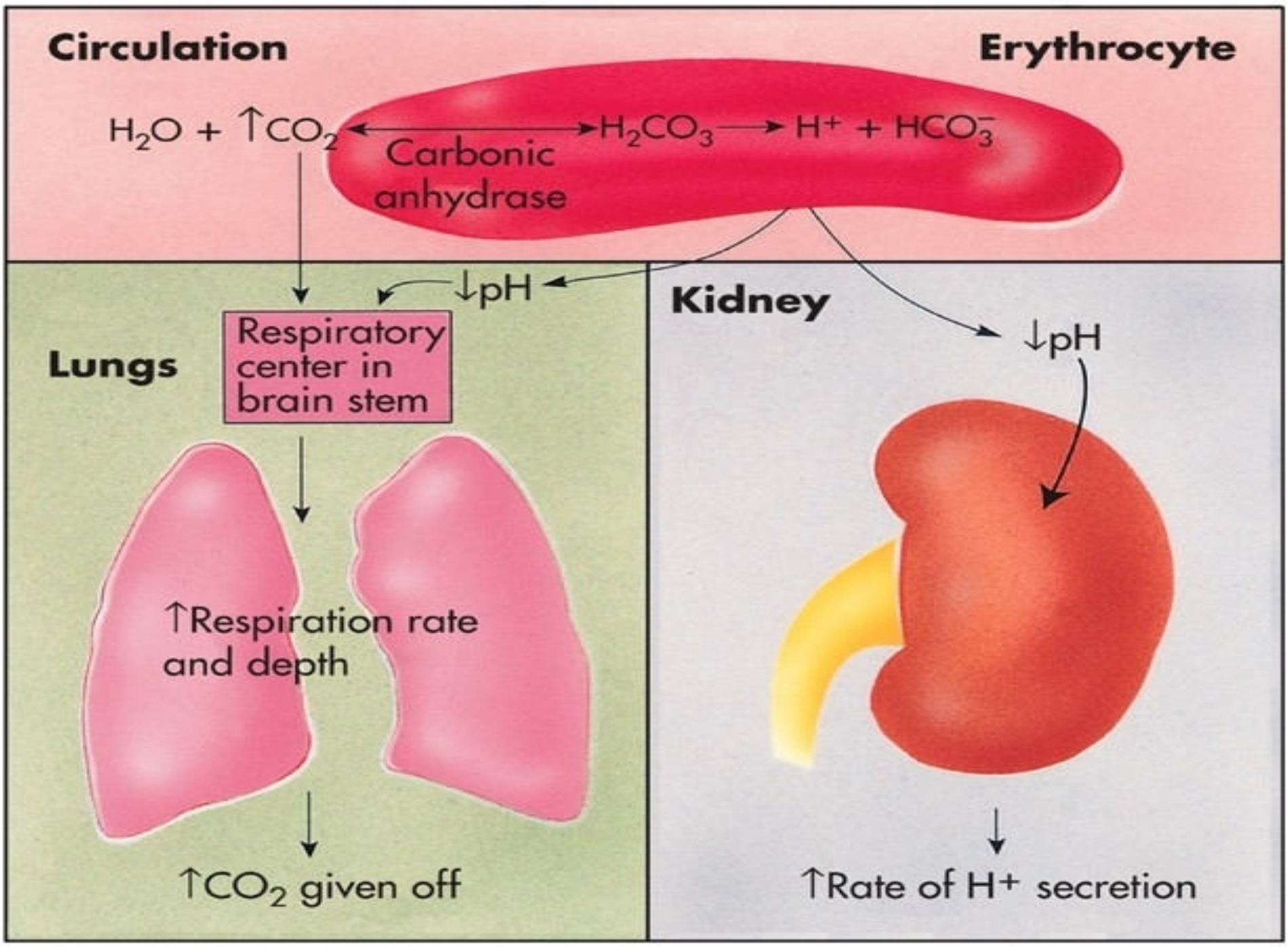
Chemical buffer system

- Bicarbonate buffer system
- Phosphate buffer system
- Protein buffer system

Second line of defense against pH shift

Physiological buffers

- Respiratory mechanism (CO_2 excretion)
- Renal mechanism (H^+ excretion)



MECHANISM FOR REGULATION OF ACID BASE BALANCE

- **Buffer system: temporary solution**
- **Respiratory mechanism provide short time regulation**
- **Renal mechanism : permanent solution**
- **Urine pH < plasma pH ,4.5-9.5**
- **Eliminate nonvolatile acid, buffered by cation (principally Na^+)**
- **Maintain alkali reserve**

Acid Base Imbalance
OR
Conditions Of Acid Base Disturbances

The Body and pH

- Homeostasis of blood pH is **tightly controlled by mechanisms of Acid Base Balance.**
- Extracellular fluid = 7.4
- Blood pH regulated to = 7.35 – 7.45

Occurrence of Acid Base Imbalance

- When Factors involved in homeostatic mechanisms to regulate Acid Base Balance fails to work efficiently.
- Does not maintain the altered pH of blood to normal constant range.
- Results into Acid Base Imbalance.

ACIDOSIS / ALKALOSIS

- Two major disturbances in **Acid-Base** balance
  - **Acidosis**
  - **Alkalosis**

Conditions Of Acid Base Imbalance

- **Acidosis /Acidemia**
  (Decreased pH/Increased H^+ ions)

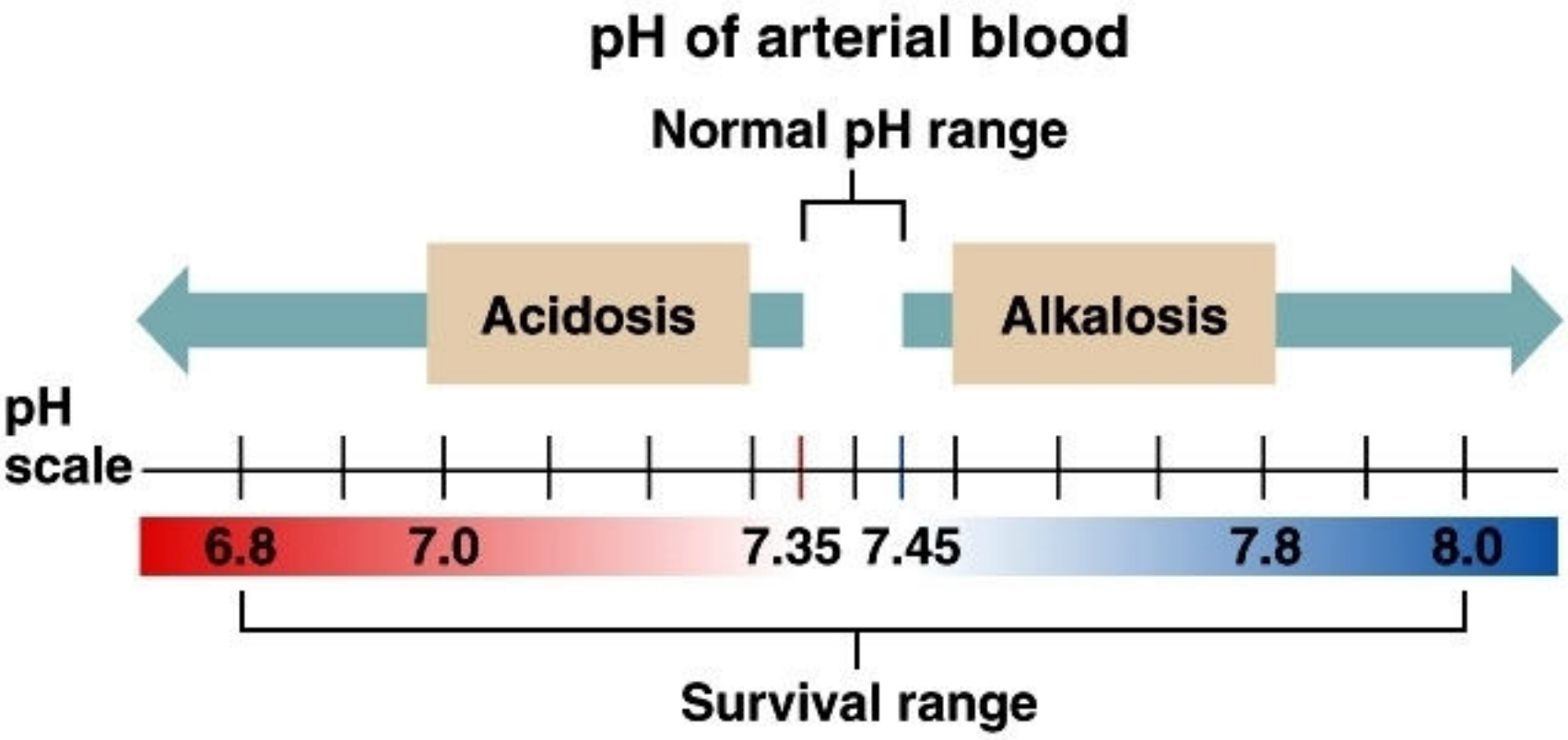
- **Alkalosis/Alkalemia**
  (Increased pH/Decreased H^+ ions)

- Acidosis (Acidemia) below 7.35
- Alkalosis (Alkalemia) above 7.45
- Blood pH < 6.8 or > 8.0 death occurs

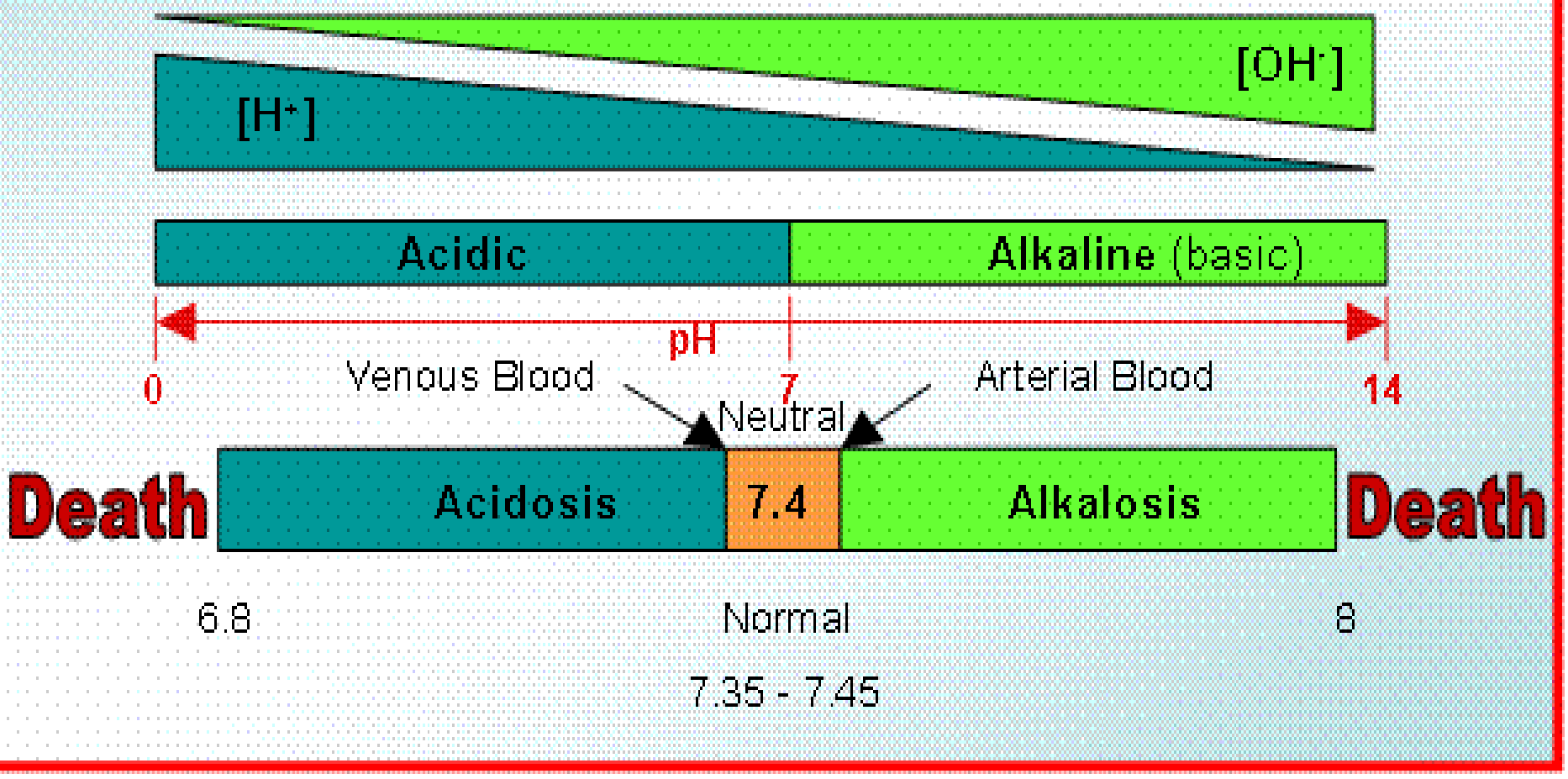
ACIDOSIS / ALKALOSIS

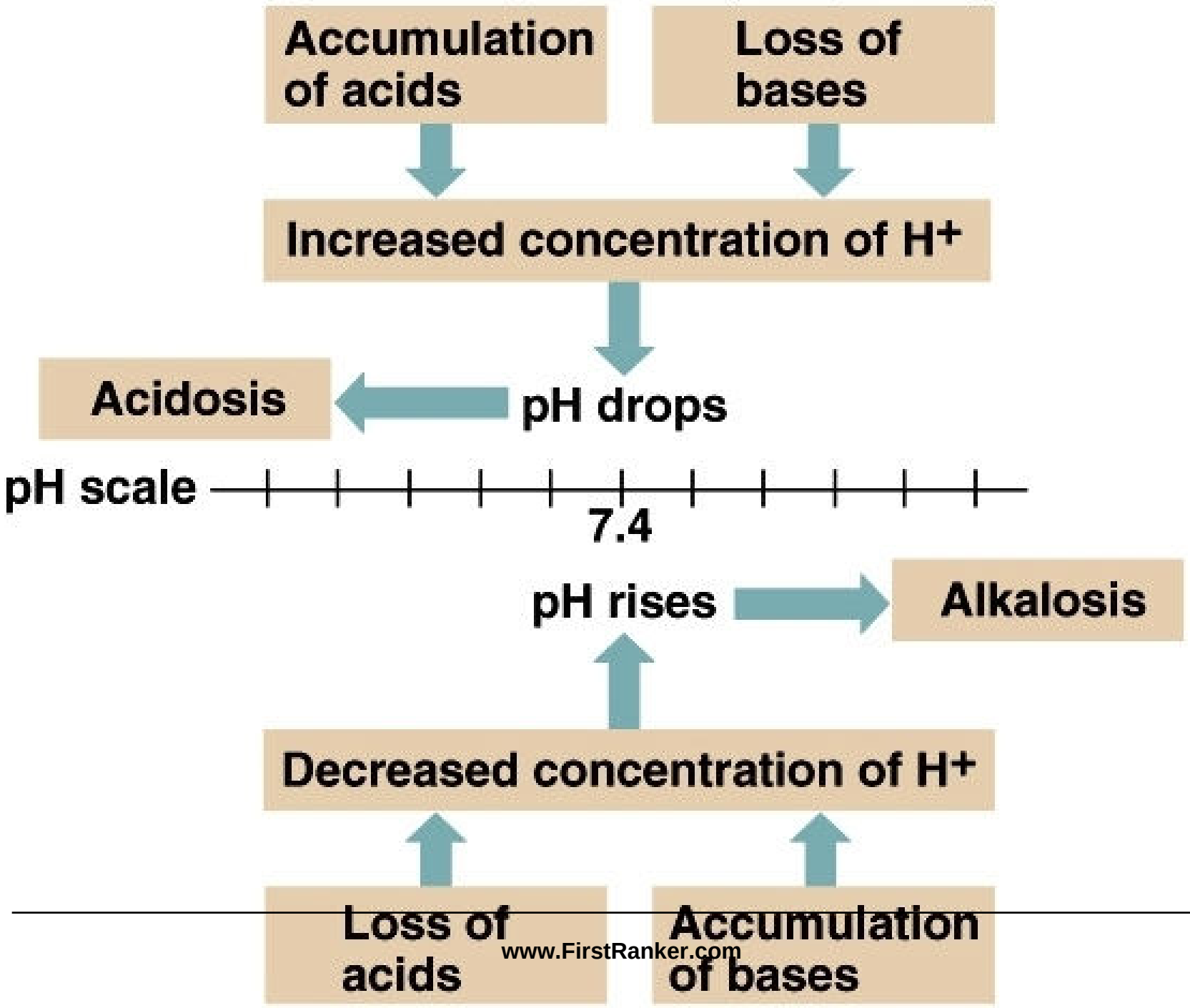
- **Acidosis**
  - A condition in which the blood has **too much acid** (or too little base), frequently resulting in a **decrease in blood pH.**

- **Alkalosis**
  - A condition in which the blood has **too much base** (or too little acid), occasionally resulting in an **increase in blood pH.**



Acid Base Balance





Effect of Altered pH

- Altered pH may seriously disturbs the vital processes.
- Might lead to fatality.

- Most enzymes function only with narrow pH ranges.
- Extremes of **pH affects the enzymatic action** by **protonation or deprotonation** at the **active sites of Enzymes**.
- Makes **Enzymes inactive**.

- **Inactivated Enzymes** affect metabolic reactions and metabolic pathways.
- **Metabolism gets deranged** .
- Leads to **metabolic syndromes.**

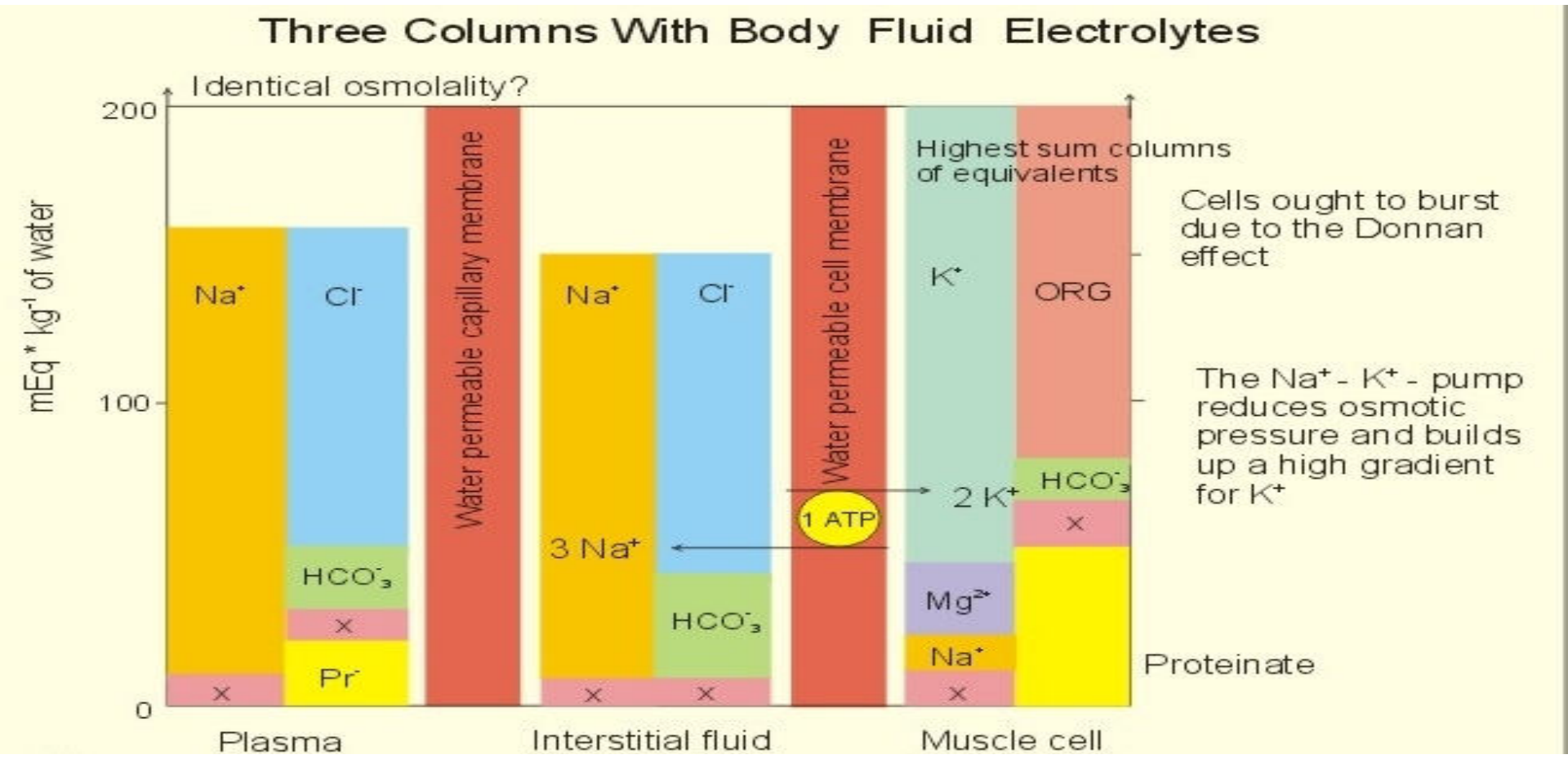
pH also affect excitability of Nerve and Muscle cells

↓ pH ↓ Excitability

↑ pH ↑ Excitability

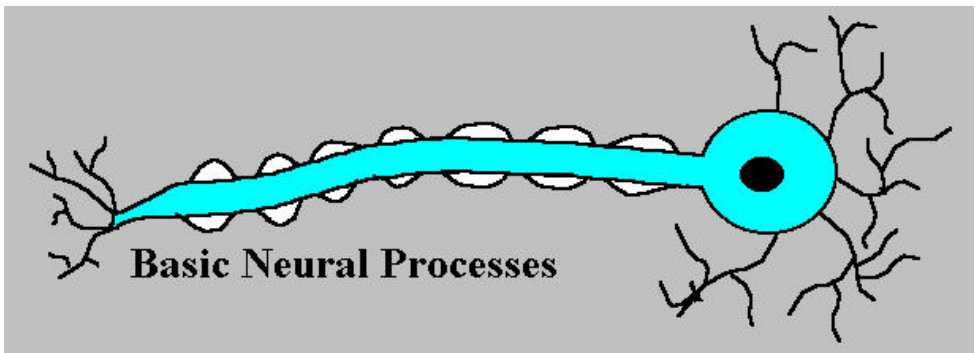
ACID-BASE REGULATION

- Enzymes, Hormones and ion distribution are all affected by Hydrogen ion concentrations



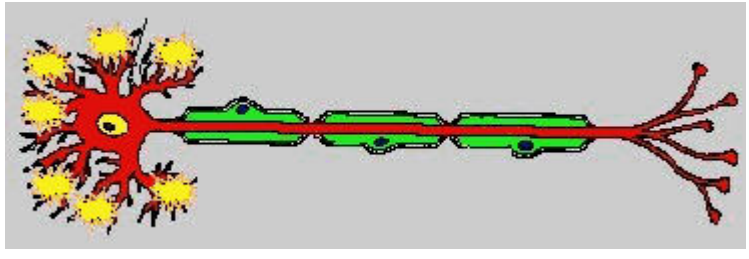
ACIDOSIS / ALKALOSIS

- pH changes have dramatic effects on normal cell function
  - **1)** Changes in excitability of nerve and muscle cells
  - **2)** Influences Enzyme activity
  - **3)** Influences **$K^{\ddagger}$** levels/Retention of K^+



CHANGES IN CELL EXCITABILITY

- **pH decrease** (more acidic) **depresses** the central **nervous system**
  - Can lead to loss of consciousness
- **pH increase** (more basic)causes **over excitability** of **nervous system.**
  - Tingling sensations, nervousness, muscle twitches



INFLUENCES ON ENZYME ACTIVITY

- pH increases or decreases can alter the shape of the enzyme rendering it non-functional
- Changes in enzyme structure can result in accelerated or depressed metabolic actions within the cell

INFLUENCES ON K^+ LEVELS

- If H^+ concentrations are high (acidosis) than H^+ is secreted in greater amounts
- This leaves less K^+ than usual excreted.
- The resultant K^+ retention can affect cardiac function and other systems

Small changes in pH can produce major disturbances

- Acid-base balance can also affect Electrolytes (Na^+, K^+, Cl^-)
- Can also affect Hormones

ACID-BASE IMBALANCE

- **Derangements** of
- **Hydrogen/Carbonic acid** (H^+/H2CO3)
- **Bicarbonate** ($HCO3^-$) concentrations

In body fluids are common in conditions of **Acid Base Imbalance**

Acid-Base Imbalances

- pH< 7.35 Acidosis
- pH > 7.45 Alkalosis

4 Types of Primary Acid-Base Disorders

Acid Base Imbalances	Biochemical Change
Respiratory Acidosis	Increased H2CO3 PCO_2
Respiratory Alkalosis	Decreased H2CO3 $\downarrow PCO_2$
Metabolic Acidosis	$\downarrow [HCO_3^-]$
Metabolic Alkalosis	$[HCO_3^-]$

Acid-Base Balance Abnormalities

I. Respiratory

Acidosis

- High pCO_2, low pH
- Pneumonia, cystic fibrosis, etc
- Kidneys

Retain bicarbonate

Alkalosis

- Low pCO_2, high pH
- Hyperventilation
- Kidneys

Secrete bicarbonate

Kidneys compensate for the problem

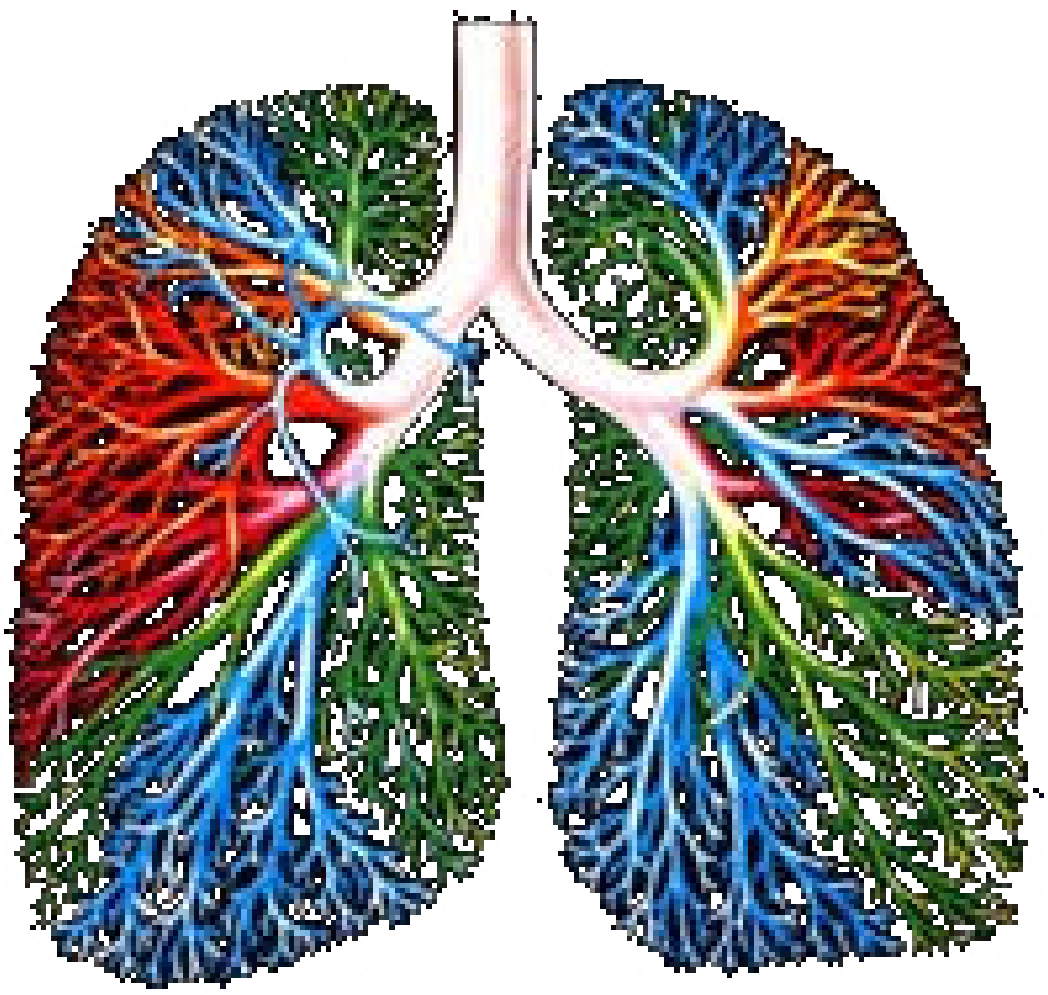
Acid-Base Balance Abnormalities

II. Metabolic

Acidosis	Alkalosis
• Low bicarbonate	• High bicarbonate
• Low pH	• High pH
• Too much alcohol	• Vomiting
• Excessive loss of bicarbonate (diarrhea)	• Excessive base intake
• Hyperventilation	• Hypoventilation

Lungs compensate for metabolism

RESPIRATORY ACIDOSIS



Respiratory Acidosis

- **Primary Carbonic acid excess**
- **Increased H2CO3/Increased pCO2**
- **Defect in respiratory centre** of brain
- **Defect in respiratory organ** system
- **Decreased elimination of H2CO3** by the lungs.
- **Hypoventilation**

- **Increased** blood levels of CO_2 above 45 mm Hg.
- **Hypercapnia** – high levels of pCO_2 in blood

RESPIRATORY ACIDOSIS

- Respiratory acidosis develops when the lungs don't expel CO_2 adequately.
- This can happen in diseases that severely affect the lungs.

- **Chronic conditions:**
  - Depression of respiratory center in brain that controls breathing rate – drugs or head trauma
  - Paralysis of respiratory or chest muscles
  - Emphysema
  - Asthma
  - Pneumonia
  - Pulmonary edema
  - Obstruction of respiratory tract
  - Congestive Cardiac Failure

HYPOVENTILATION
Causes Respiratory Acidosis

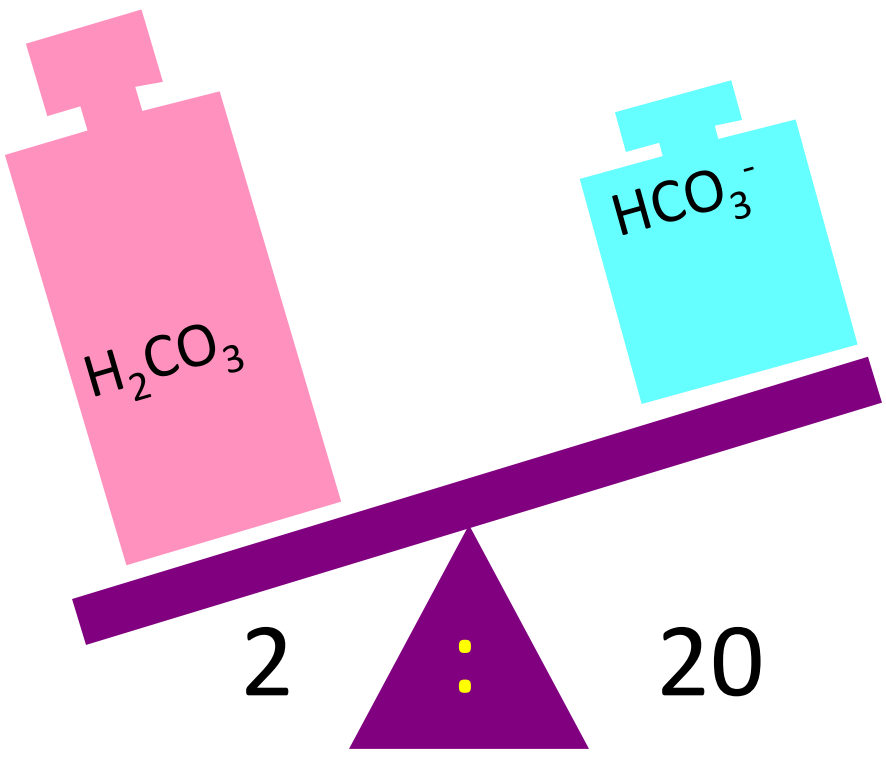
- Hypo = “Under”

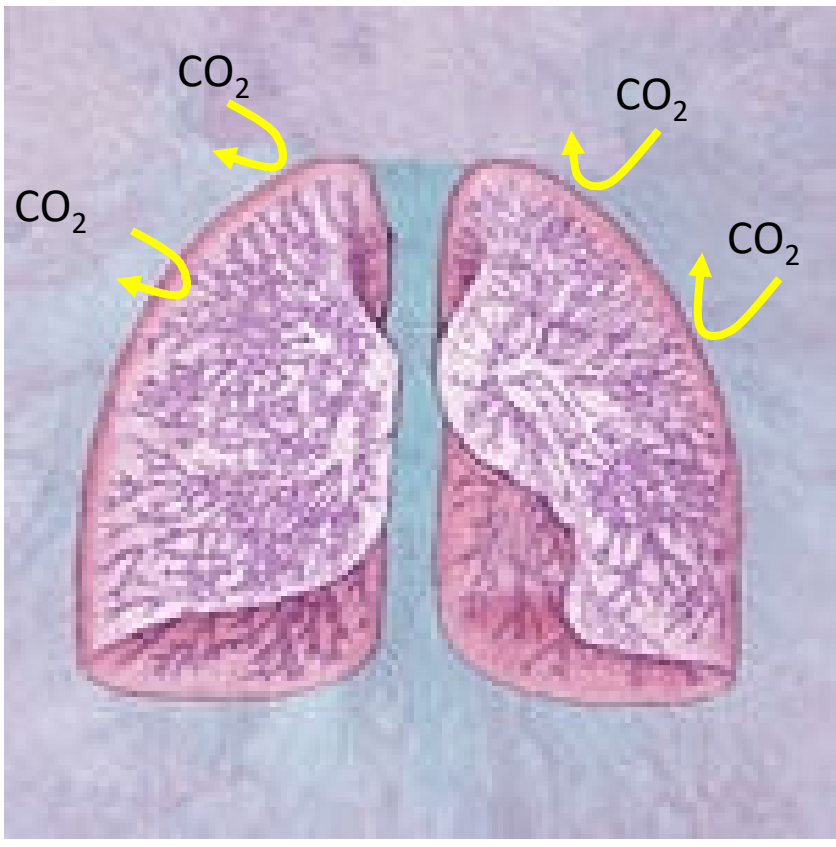
↓ Elimination of CO_2

↑ H^+

↓ pH

RESPIRATORY ACIDOSIS

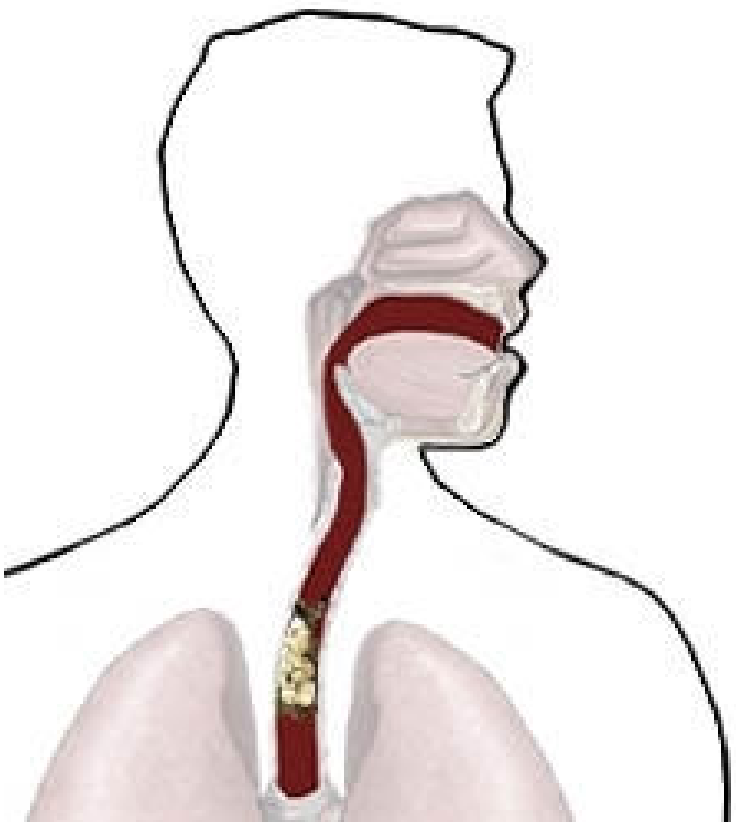


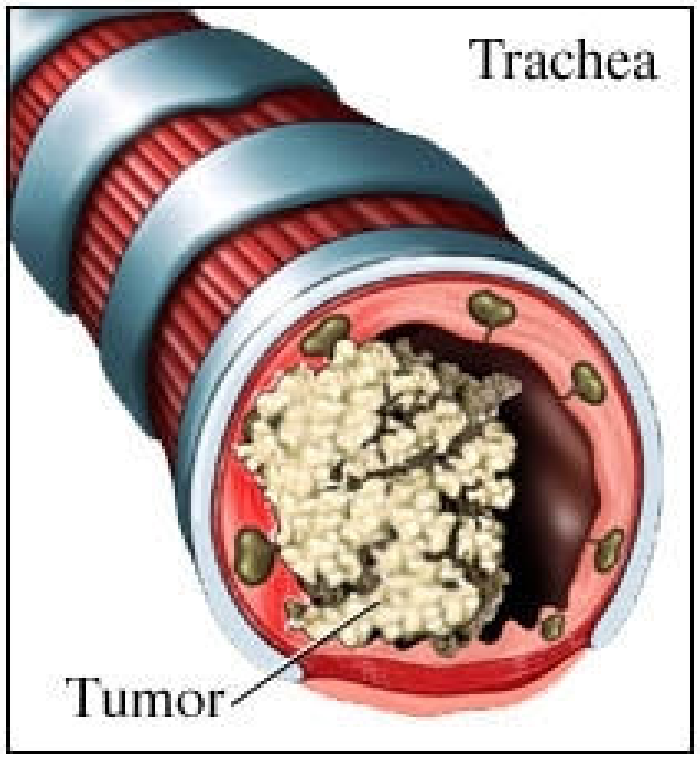


-breathing is suppressed holding CO_2 in body
-pH = 7.1

RESPIRATORY ACIDOSIS

- **1) Obstruction of air passages**
  - Vomit, Anaphylaxis, Tracheal Cancer





RESPIRATORY ACIDOSIS

- **2) Decreased Respiration**
  - Shallow, slow breathing
  - Depression of the respiratory centers in the brain which control breathing rates
    - Drug overdose

RESPIRATORY ACIDOSIS

- **4) Collapse of lung**
  - Compression injury, open thoracic wound

Left lung collapsed

Respiratory Acidosis

- Acute conditions:
  - Adult Respiratory Distress Syndrome
  - Pulmonary edema
  - Pneumothorax

Compensation for Respiratory Acidosis

- **Kidneys eliminate hydrogen ion** and **retain bicarbonate ions.**

Signs and Symptoms of Respiratory Acidosis

- Breathlessness
- Restlessness
- Lethargy and disorientation
- Tremors, convulsions, coma
- Respiratory rate rapid, then gradually depressed
- Skin warm and flushed due to vasodilation caused by excess CO_2

Treatment of Respiratory Acidosis

- Restore ventilation
- IV lactate solution
- Treat underlying dysfunction or disease

RESPIRATORY ALKALOSIS

Respiratory Alkalosis

- **Primary Carbonic acid deficit**
- **Decreased H2CO3**
- pCO_2 less than 35 mm Hg (hypocapnea)
- Most common acid-base imbalance
- Primary cause is **hyperventilation**
- Washes out excessive quantity of H2CO3 through expiration process of lungs.

- Stimulation of respiratory centre in brain
- Hyperventilation

Respiratory Alkalosis

- **Conditions that stimulate respiratory center:**
  - Oxygen deficiency at high altitudes
  - Pulmonary disease and Congestive heart failure – caused by hypoxia
  - Respiratory center lesions
  - Acute anxiety
  - Fever, anemia
  - Early salicylate intoxication
  - Cirrhosis
  - Gram-negative sepsis/Meningitis

RESPIRATORY ALKALOSIS

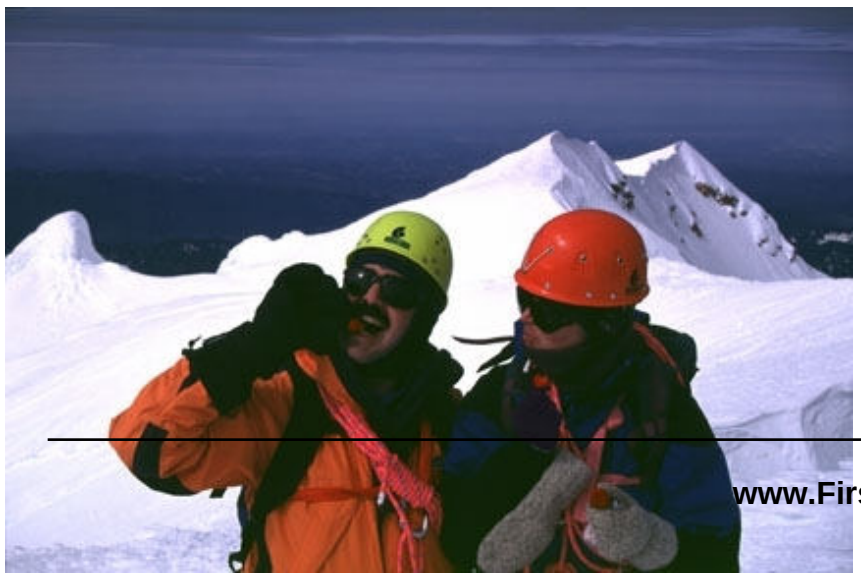
- **Anxiety** is an emotional disturbance
- The most common cause of **hyperventilation,** and thus **respiratory alkalosis**, is noted in **anxiety**

RESPIRATORY ALKALOSIS

- Respiratory center lesions
  - Damage to brain centers responsible for monitoring breathing rates
    - Tumors
    - Strokes

RESPIRATORY ALKALOSIS

- **High Altitude**
  - Low concentrations of O_2 in the arterial blood reflexly stimulates ventilation in an attempt to obtain more O_2
  - Too much CO_2 is "blown off" in the process

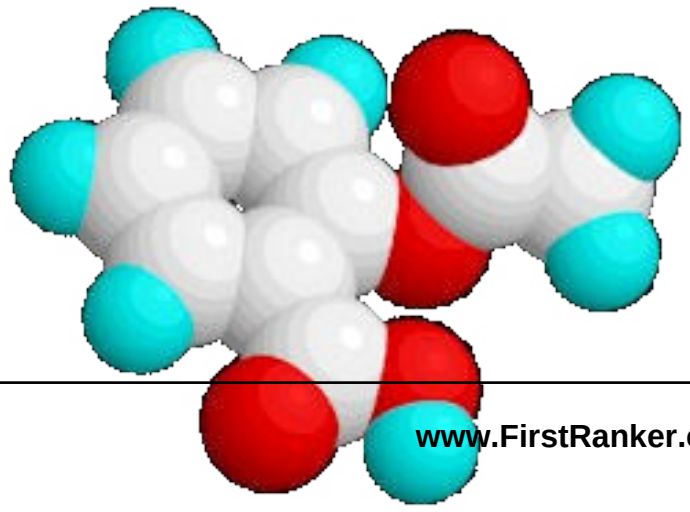


RESPIRATORY ALKALOSIS

- **Fever**
  - Rapid shallow breathing blows off too much CO_2

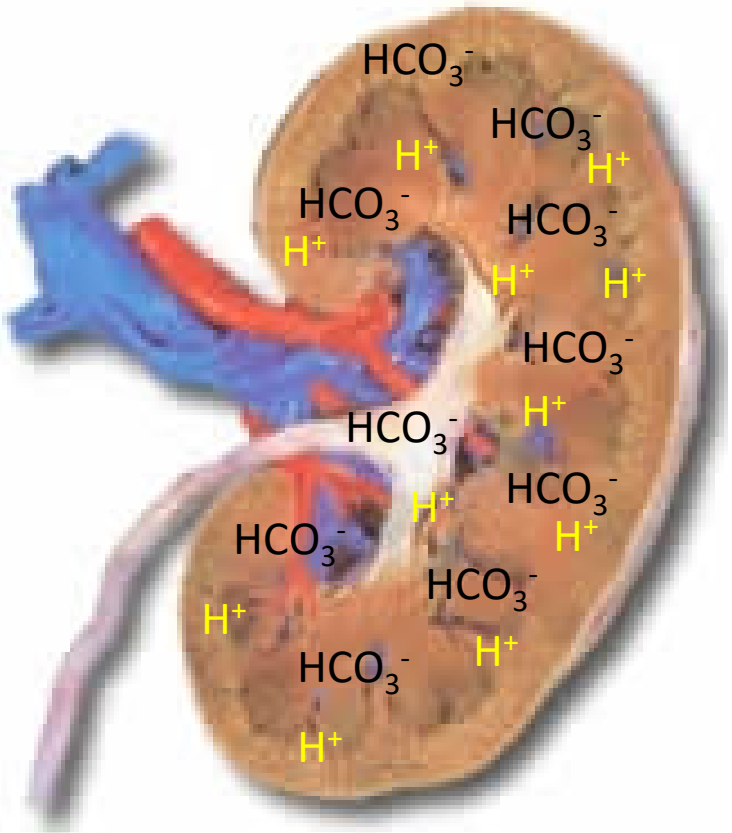
RESPIRATORY ALKALOSIS

- **Salicylate poisoning (Aspirin overdose)**
  - Ventilation is stimulated without regard to the status of O_2, CO_2 or H^+ in the body fluids



RESPIRATORY ALKALOSIS

- Kidneys compensate by:
  - **Retaining hydrogen ions**
  - **Increasing bicarbonate excretion**



HYPERVENTILATION
Causes Respiratory Alkalosis

- **Hyper = "Over"**

↑ **Elimination of CO_2**

↓ H^+

↑ pH

Compensation of Respiratory Alkalosis

- If **kidneys** are functioning normal
- The conditions of respiratory acidosis or alkalosis are compensated.
- **Kidneys conserve hydrogen ion**
- **Excrete bicarbonate ion**

Treatment of Respiratory Alkalosis

- Treat underlying cause
- Breathe into a paper bag
- IV Chloride containing solution Cl^- ions replace lost bicarbonate ions

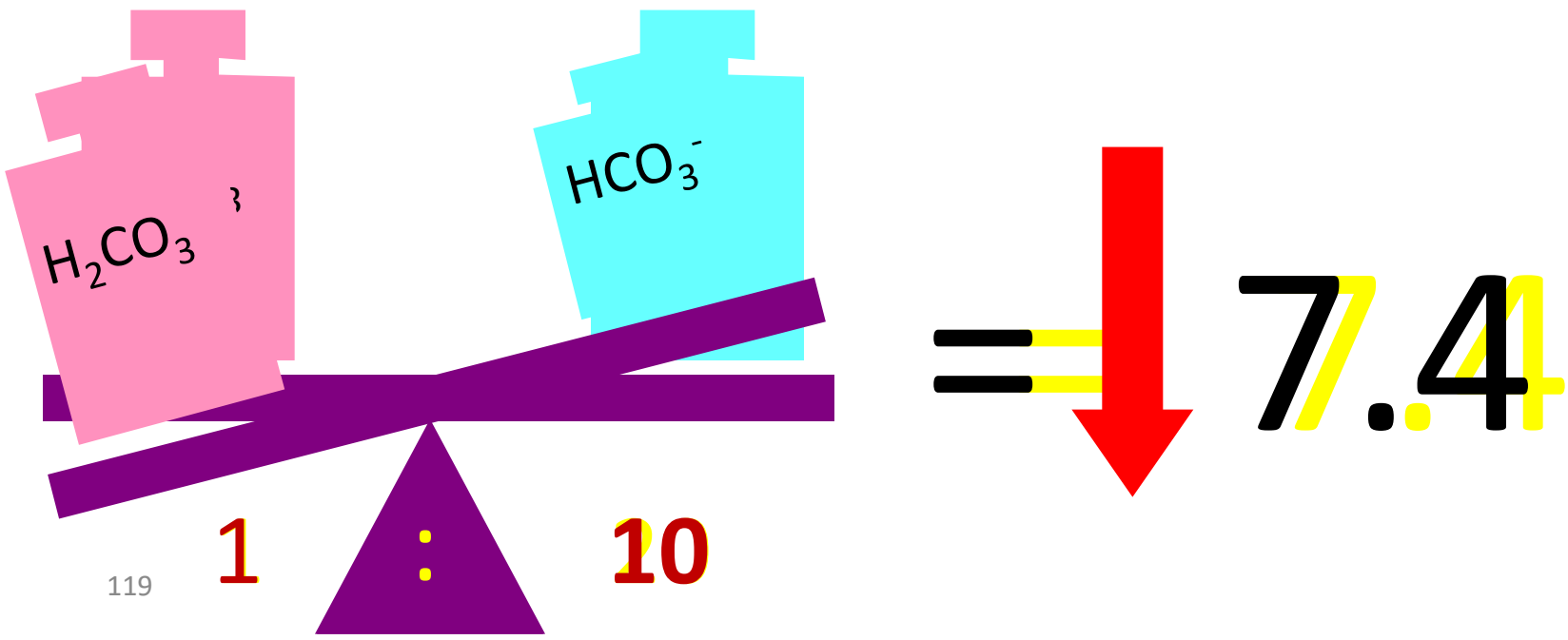
METABOLIC ACIDOSIS

Metabolic Acidosis

- **Primary Alkali deficit**
- **Bicarbonate deficit** - blood concentrations of bicarbonate drop below 22mEq/L
- Causes:
  - **Loss of bicarbonate through diarrhea or renal dysfunction.**
  - **Overproduction production of acids (lactic acid or ketones)**
  - **Failure of kidneys to excrete H^+**

METABOLIC ACIDOSIS

- Occurs when there is a decrease in the normal 20:1 ratio
  - Decrease in blood **pH** and bicarbonate level
- Excessive H^+ or decreased HCO_3^-



METABOLIC ACIDOSIS

- Any acid-base imbalance not attributable to CO_2 is classified as metabolic
  - Metabolic production of **Acids**
  - Or loss of **Bases**

METABOLIC ACIDOSIS

- The causes of metabolic acidosis can be grouped into **five** major categories
  - **1) Ingesting** an acid or a substance that is metabolized to acid
  - **2) Abnormal Metabolism**
  - **3) Kidney Insufficiencies**
  - **4) Strenuous Exercise**
  - **5) Severe Diarrhea**

METABOLIC ACIDOSIS

- **1) Ingesting An Acid**
  - Most substances that cause acidosis when ingested are considered poisonous
  - Examples include **wood alcohol** (methanol) and antifreeze (ethylene glycol)

  - However, even an **overdose** of **aspirin** (acetylsalicylic acid) can cause **metabolic acidosis**

METABOLIC ACIDOSIS

- **2) Abnormal Metabolism**
  - The body can produce excess acid as a result of several diseases
    - **Ketoacidosis**
    - **Type I Diabetes Mellitus**
    - **Uncontrolled Diabetes mellitus**
    - **Prolonged Starvation**
    - **Lacticacidosis**
    - **Shock**
    - **Haemorrhage**
    - **Violent Exercise-**

METABOLIC ACIDOSIS

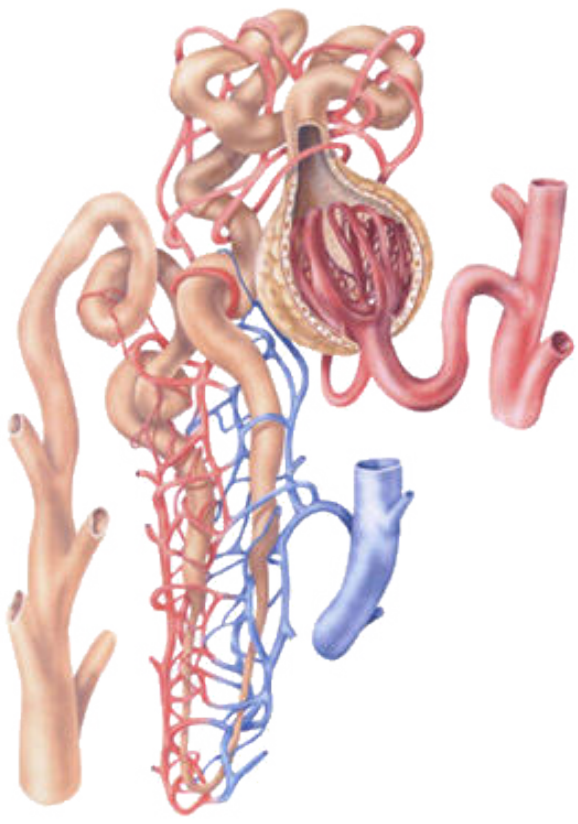
- Unregulated diabetes mellitus causes **ketoacidosis**
  - Body metabolizes fat rather than glucose
  - Accumulations of metabolic acids **(Keto Acids)** cause an increase in plasma $H^{\ddagger}$

METABOLIC ACIDOSIS

- **3) Kidney Insufficiencies**
  - This type of kidney malfunction is called **renal tubular acidosis** or **uremic acidosis** and may occur in people with kidney failure or with abnormalities that affect the kidneys' **ability to excrete acid**

METABOLIC ACIDOSIS

- **3) Kidney Insufficiencies**
  - Kidneys may be **unable to rid** the plasma of even the normal amounts of H^+ generated from metabolic acids
  - Kidneys may be also **unable to conserve** an adequate amount of HCO_3^- to buffer the normal acid load



METABOLIC ACIDOSIS

- **4) Strenuous Exercise**
  - Muscles resort to anaerobic glycolysis during strenuous exercise
  - Anaerobic respiration leads to the production of **large amounts** of **lactic acid**

METABOLIC ACIDOSIS

- **5) Severe Diarrhea**
  - Fluids rich in **HCO_3^-** are released and reabsorbed during the digestive process
  - During **diarrhea** this **HCO_3^-** is **lost from the body** rather than reabsorbed

METABOLIC ACIDOSIS

- **5) Severe Diarrhea**
  - The loss of HCO_3^- without a corresponding loss of H^+ lowers the pH
  - Less HCO_3^- is available for buffering H^+
  - Prolonged deep (from duodenum) vomiting can result in the same situation

Symptoms of Metabolic Acidosis

- Headache, lethargy
- Nausea, vomiting, diarrhea
- Coma
- Death

Compensation for Metabolic Acidosis

- Increased ventilation.
- Renal excretion of hydrogen ions if possible.
- K^+ exchanges with excess H^+ in ECF.
- H^+ into cells, K^+ out of cells.

Treatment of Metabolic Acidosis

- **IV lactate solution**

METABOLIC ALKALOSIS

Metabolic Alkalosis

- **Bicarbonate Excess** - concentration in blood is greater than 26 mEq/L
- Causes:
  - **Excess vomiting = loss of stomach acid**
  - Excessive use of alkaline drugs
  - Certain diuretics
  - Endocrine disorders
  - Heavy ingestion of antacids
  - Severe dehydration
  - Cushings Syndrome
  - Prolonged exposure to x rays and UV rays

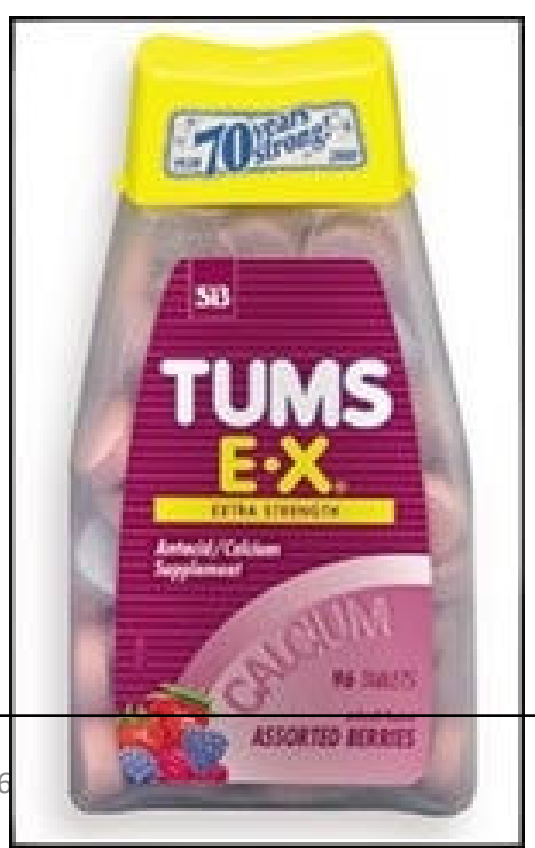
METABOLIC ALKALOSIS

- Elevation of **pH** due to an increased 20:1 ratio
  - May be caused by:
    - An **increase** of bicarbonate
    - A **decrease** in hydrogen ions
  - Imbalance again cannot be due to **CO_2**
  - Increase in **pH** which has a non-respiratory origin

7.4

METABOLIC ALKALOSIS

- Can be the result of:
  - **1) Ingestion of Alkaline Substances**
  - **2) Vomiting (loss of HCl)**



METABOLIC ALKALOSIS

- Baking soda ($NaHCO_3$) often used as a remedy for gastric hyperacidity
  - $NaHCO_3$ dissociates to Na^+ and HCO_3^-

Compensation for Metabolic Alkalosis

- Alkalosis most commonly occurs with renal dysfunction, so can't count on kidneys.
- Respiratory compensation difficult – hypoventilation limited by hypoxia.

Symptoms of Metabolic Alkalosis

- Respiration slow and shallow
- Hyperactive reflexes ; tetany
- Often related to depletion of electrolytes
- Atrial tachycardia
- Dysrhythmias

Treatment of Metabolic Alkalosis

- Electrolytes to replace those lost
- IV chloride containing solution
- Treat underlying disorder

Acidosis

- Principal effect of **acidosis is depression of the CNS** through ↓ in synaptic transmission.
- Generalized weakness
- **Deranged CNS function** the greatest threat
  - **Severe acidosis causes**
    - **Disorientation**
    - **Coma**
    - **Death**

Alkalosis

- **Alkalosis causes over excitability of the central and peripheral nervous systems.**
- Numbness
- Light headedness
  - **Severe Alkalosis causes :**
    - Nervousness
    - muscle spasms or Tetany
    - Convulsions
    - Loss of consciousness
    - Death

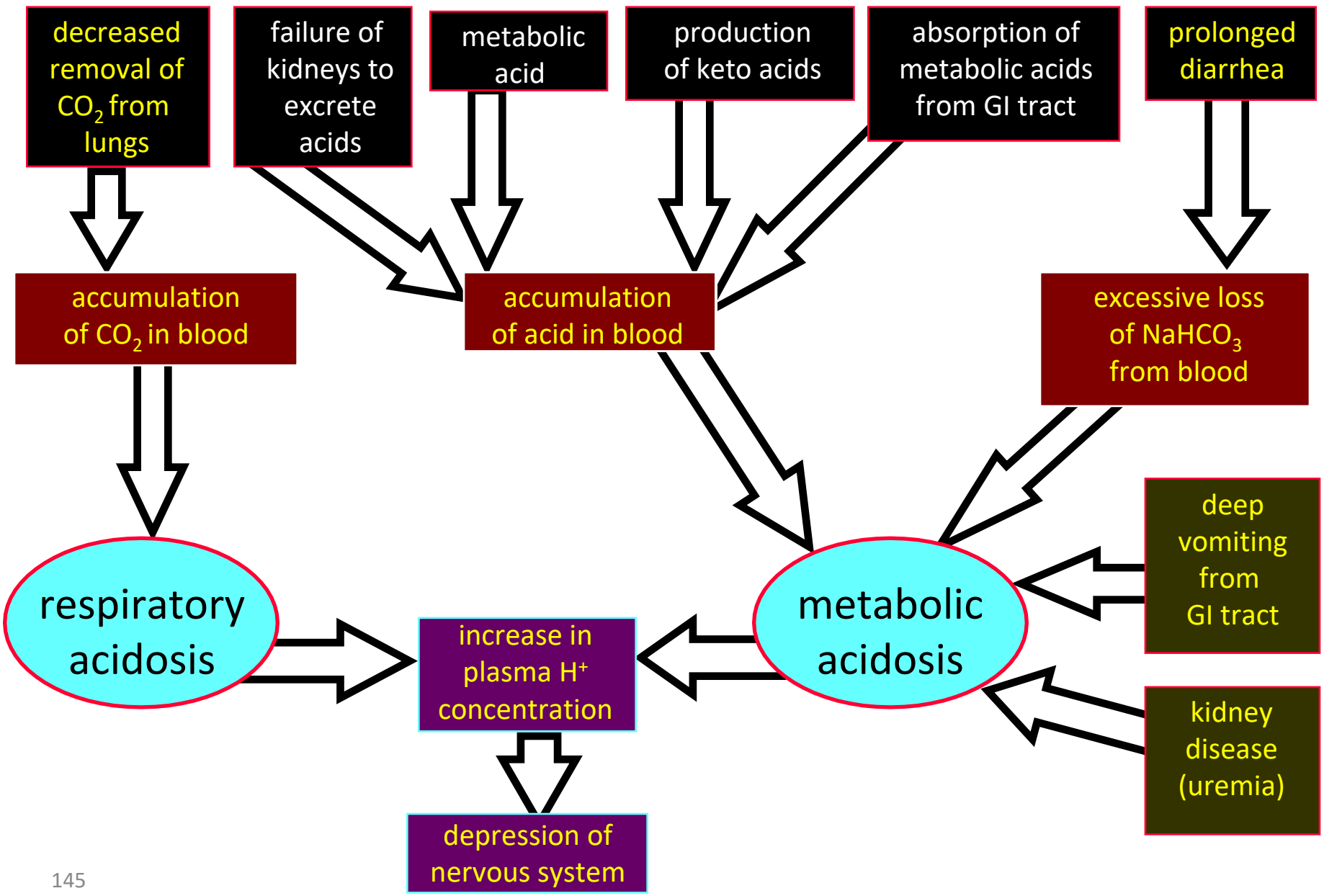
Compensation Of Acid Base Imbalance

- The body response to acid-base imbalance is called **compensation**
- May be **complete compensation** if altered pH brought back within normal limits
- **Partial compensation** if pH range is still outside norms.
- **Uncompensated** if pH range is very out from norms.

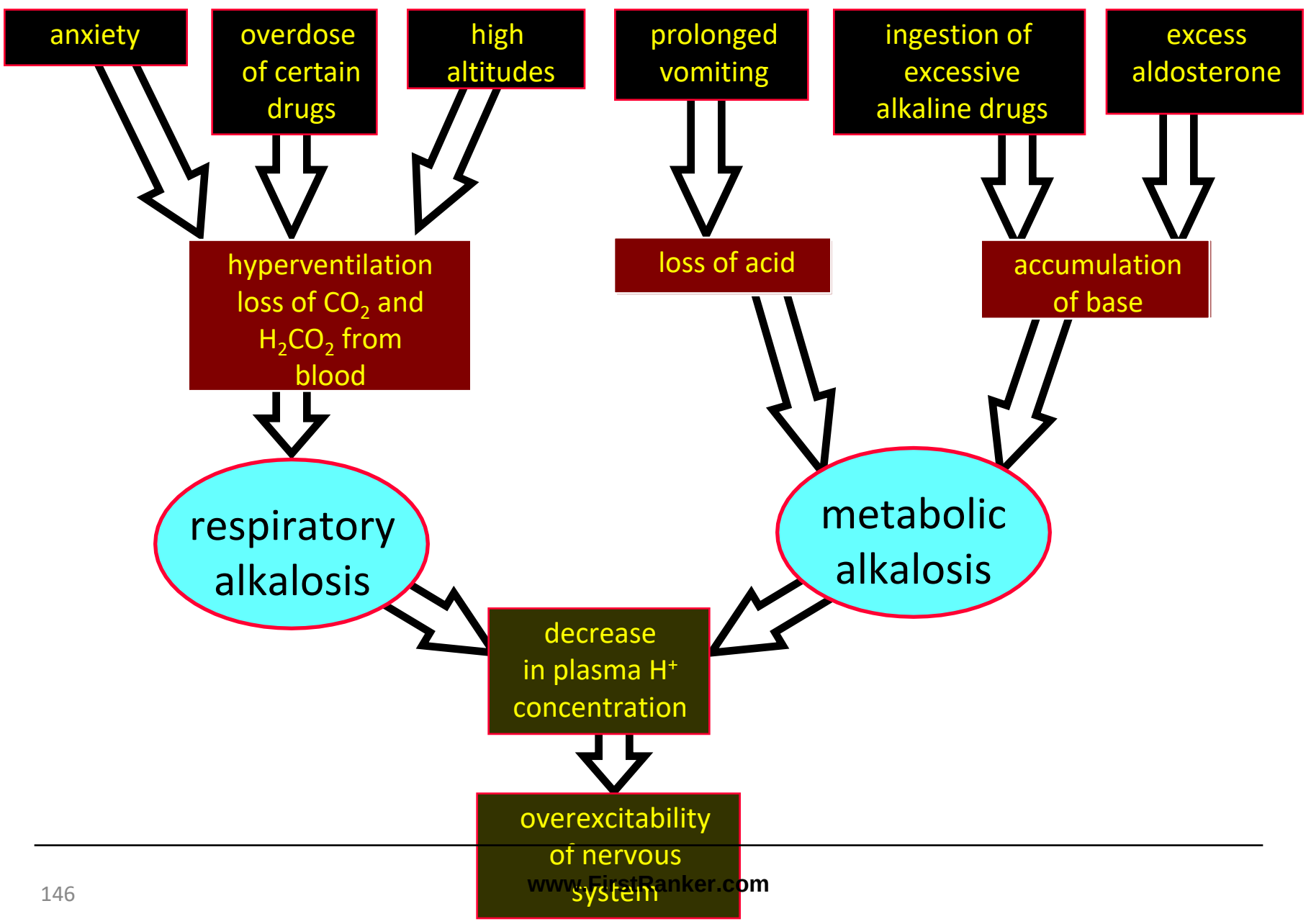
- If **underlying problem is respiratory**, renal mechanisms can bring about **metabolic compensation.**

- If **underlying problem is metabolic**, hyperventilation or hypoventilation can help : **respiratory compensation**.

ACIDOSIS



ALKALOSIS



Organ dysfunction And Acid Base Imbalance

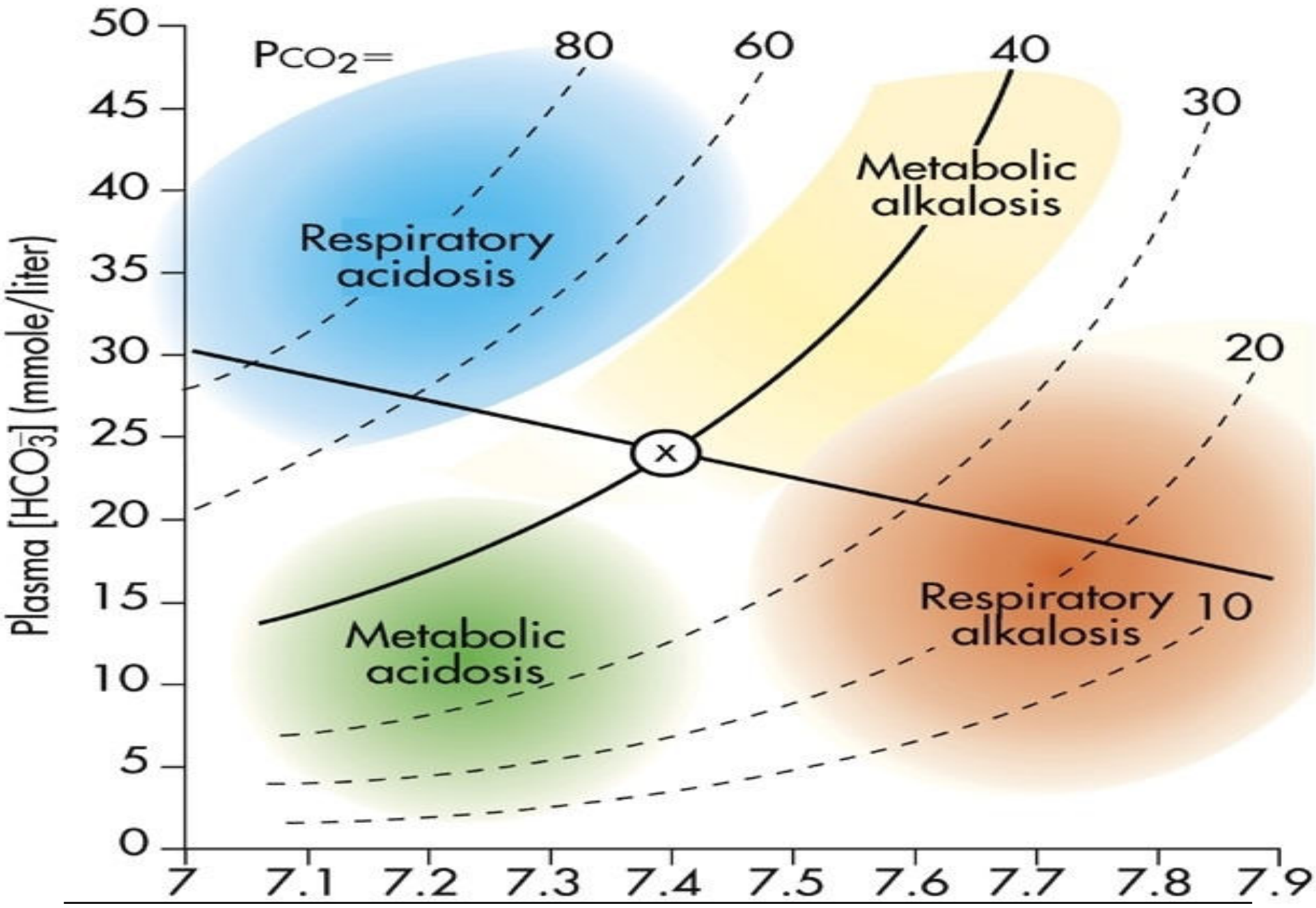
- CNS – respiratory acidosis (suppression) and alkalosis (stimulation)
- Pulmonary – respiratory acidosis (COPD) and alkalosis (hypoxia, pulmonary embolism)
- Cardiac – respiratory alkalosis, respiratory acidosis, metabolic acidosis (pulmonary edema)
- GIT – metabolic alkalosis (vomiting) and acidosis (diarrhea)
- Liver – respiratory alkalosis, metabolic acidosis (liver failure)
- Kidney – metabolic acidosis (RTA) and alkalosis (1st Aldosterone)

Organ Dysfunction

- Endocrine
  - **Diabetes mellitus** – metabolic acidosis
  - **Addisons Disease**/Adrenal insufficiency – **metabolic acidosis.**(Decreased H^+ ions excretion)
  - **Cushing's Syndrome** – **metabolic alkalosis**
    (Increased Cortisol- Increased H^+ ions excretion)
  - **Primary aldosteronism** – metabolic alkalosis
- Drugs/toxins
  - Toxic alcohols – metabolic acidosis
  - ASA/Aspirin – metabolic acidosis and respiratory alkalosis(Causes Hyperventilation)
  - Theophylline overdose – respiratory alkalosis

ACID – BASE DISORDERS

Clinical State	Acid-Base Disorder
Pulmonary Embolus	Respiratory Alkalosis
Cirrhosis	Respiratory Alkalosis
Pregnancy	Respiratory Alkalosis
Diuretic Use	Metabolic Alkalosis
Vomiting	Metabolic Alkalosis
Chronic Obstructive Pulmonary Disease	Respiratory Acidosis
Shock	Metabolic Acidosis
Severe Diarrhea	Metabolic Acidosis
Renal Failure	Metabolic Acidosis
Sepsis (Bloodstream Infection)	Respiratory Alkalosis, Metabolic Acidosis



Anion Gap

- Sum of anion and cations is always equal
- Sodium and Potassium accounts for 95% of cations
- Chloride and bicarbonate accounts for 68% of anions
- There is difference between measured anion and cation
- The unmeasured anions constitute the ANION GAP.

- They are protein anions ,sulphates ,phosphates and organic acid(Unmeasured Anions)
- AG can be calculated as $(Na^+ + K^+)—(HCO_3^- + Cl^-)$
- High anion gap acidosis: renal failure, DM
- Normal anion gap acidosis: diarrhea
- Hyperchloremic acidosis

Calculation Of Anion Gap

- $Na^+ + K^+ = Cl^- + HCO3^- + A^-$
- 136+ 4 = 100 + 25
- A^- = 15 mEq/L

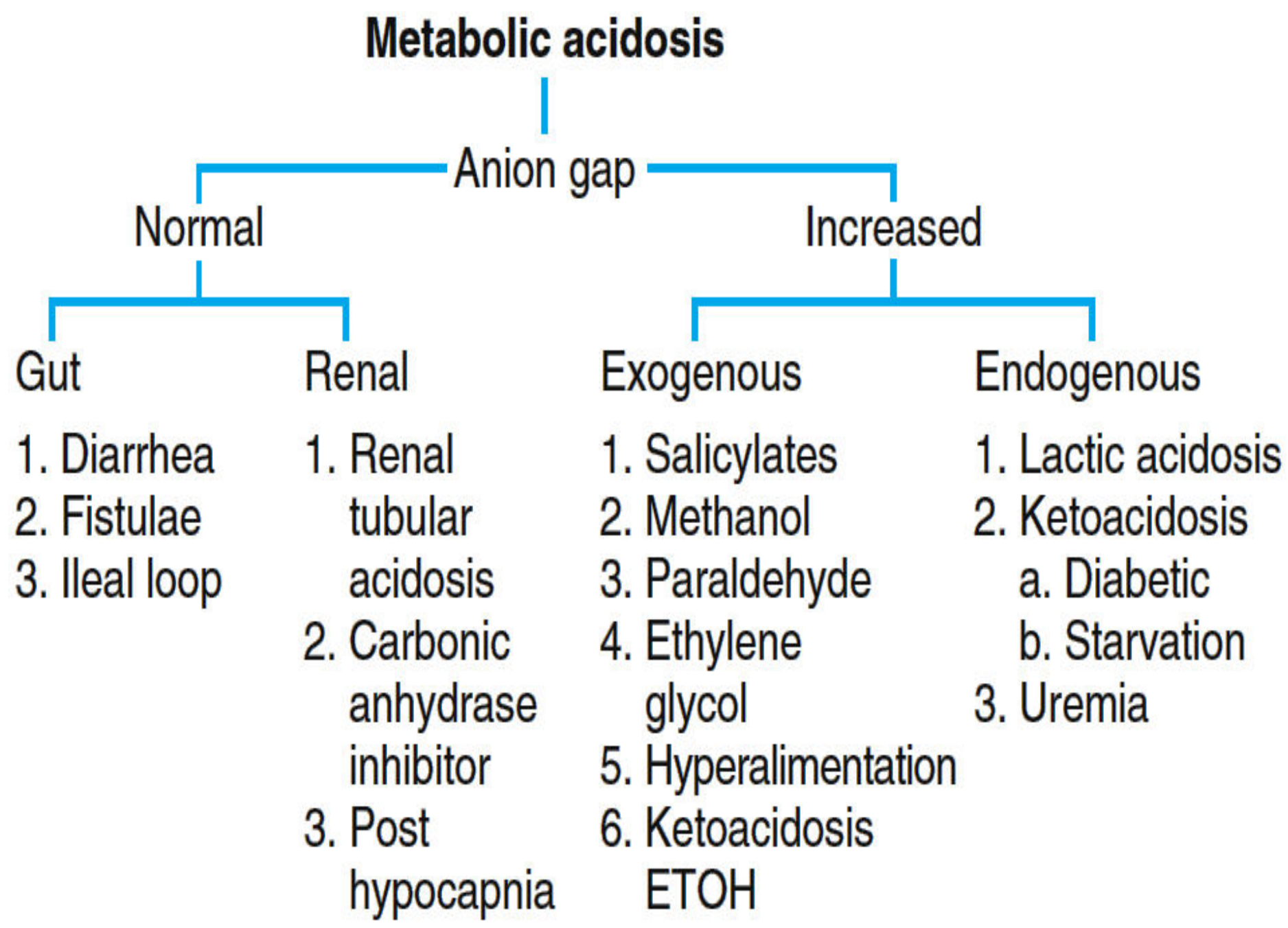
- Normal AG is typically 12 ± 4 mEq/L.
- If AG is calculated using K+, the normal AG is 16 ± 4 mEq/L

Significance of Anion Gap Calculation

- Calculation of Anion gap and its values help in diagnosing conditions of Acid Base Balance and Imbalance.

- The **anion gap is increased** in conditions such as **metabolic acidosis**:
- That result from elevated levels of metabolic acids (metabolic acidosis)
  - Lactic acidosis
  - Diabetic Ketoacidosis
  - Renal Failure

- A low anion gap occurs in conditions that cause a fall in unmeasured anions
- (primarily albumin) OR a rise in unmeasured cations

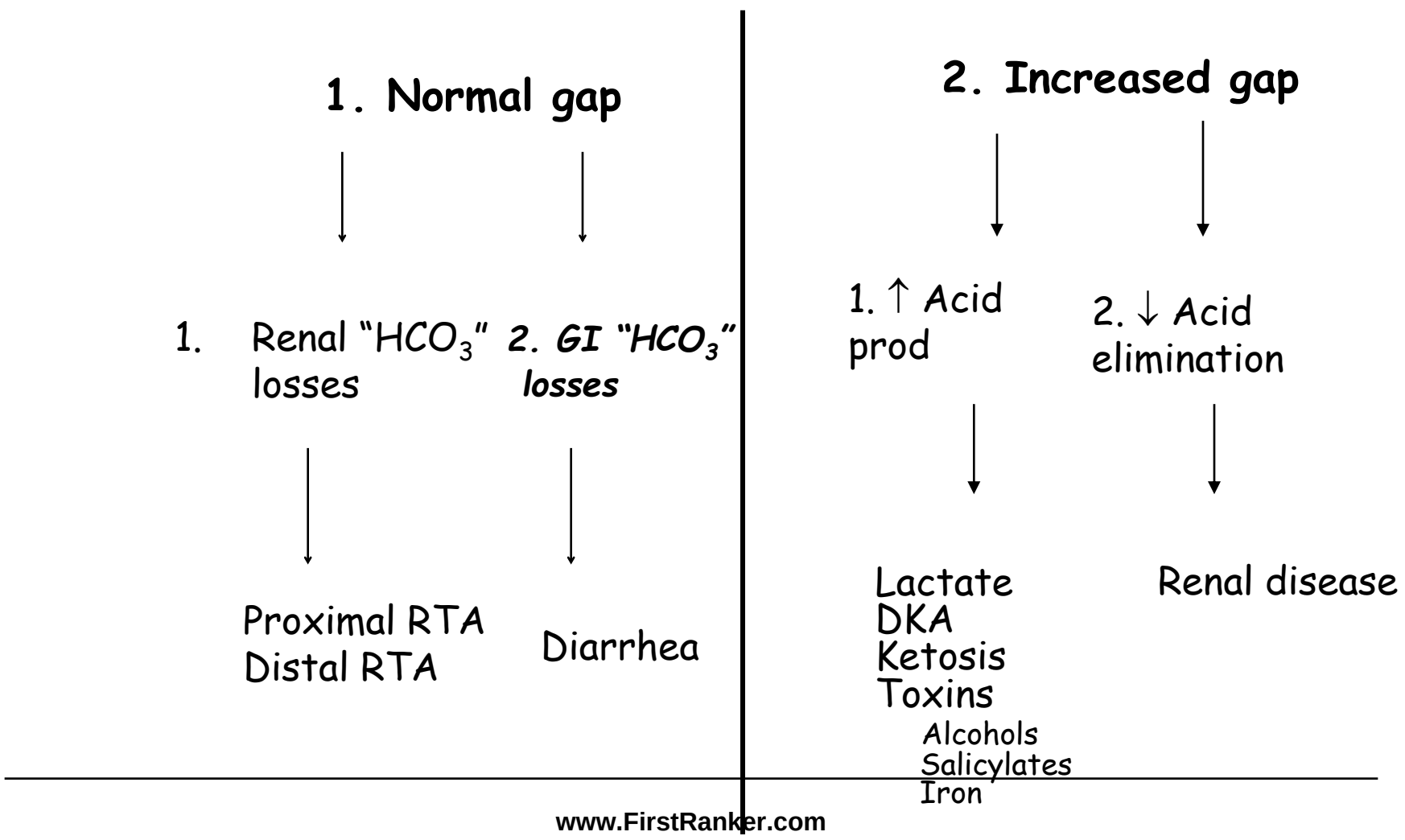


Calculate the Anion Gap

- 1. Calculate the anion gap as described.
- 2. An anion gap ,over 25 suggests a severe metabolic acidosis.
- 3. Causes of an high anion gap: ethylene glycol, lactic acid, methanol, paraldehyde, aspirin, renal failure, ketoacidosis (diabetic or ethanol).

Anion Gap Acidosis:

- Anion gap >12 mmol/L; caused by a decrease in [HCO3 -]
- Balanced by an increase in an unmeasured acid ion from either endogenous production or exogenous ingestion (**normochloremic acidosis**).



Anion Gap.

$Gap = Na^+ + K^+ - Cl^- - HCO_3^-$

15 = 140 + 5 - 105 - 25 mMol/L

- A gap greater than 30 indicates a significant concentration of unmeasured anions.

Henderson Hasselbalch Equation

- pH= pka +log [$HCO3^-$]/[H2CO3]
- At pH 7.4 the ratio of $HCO3^-$/H2CO3 is 1:20.
- A buffer is most effective when pH=pKa
- When concentration of salt and acid are equal.

Significance of Henderson Hasselbalch Equation

- The equation helps in calculating pH of Buffers.
- The equation helps in assessing status of Acid Base balance.

Stepwise Approaches

- History & physical examination
- **Arterial blood gas for pH, pCO_2, (HCO_3)**
  - Use the HCO_3 from ABG to determine compensation
- Serum Na, K, Cl, CO_2 content
  - Use CO_2 content to calculate anion gap
- Calculate anion gap
  - Anion gap = {Na - (Cl + CO_2 content)}
- Determine appropriate compensation
- Determine the primary cause

DIAGNOSTIC LAB VALUES & INTERPRETATION

- **Arterial Blood Gas(ABG)Analyzer** determines Acid Base Balance and Imbalance.

Diagnosis of Acid-Base Imbalances

1. **Note** whether **the pH** is low (acidosis) or high (alkalosis)
2. Decide which value, pCO_2 or HCO_3^- , is outside the normal range
3. If the cause is a **change in pCO_2,/H2CO3** the problem **is respiratory.**
4. If **the change is in HCO_3^-** the problem is **metabolic.**

Normal Arterial Blood Gas (ABG) Lab Values:

- Arterial pH: 7.35 – 7.45
- HCO_3^-: 22 – 26 mEq/L
- PCO_2: 35 – 45 mmHg
- TCO_2: 23 – 27 mmol/L
- PO_2: 80 – 100 mmHg
- Base Excess: -2 to +2
- Anion Gap: 12 – 14 mEq/L

Example

- A patient is in intensive care because he suffered a severe myocardial infarction 3 days ago. The lab reports the following values from an arterial blood sample:
  - pH 7.3
  - HCO3- = 20 mEq / L (22 - 26)
  - pCO2 = 32 mm Hg (35 - 45)

Diagnosis

- Metabolic acidosis
- With compensation

Questions

- **Long Essays.**

- What is acid-base balance? Describe the homeostatic mechanism by which the blood pH is regulated.
- **Short Notes**

- Blood Buffer System.
- Role of Kidney in acid-base balance.
- Hb as Buffer system.
- Acid-Base imbalance.
- Metabolic Acidosis.
- Difference between acidosis & alkalosis.
- Anion Gap.

END

ACID - BASE BALANCE

THANKS