Acid Base System

Dr Sitelbanat

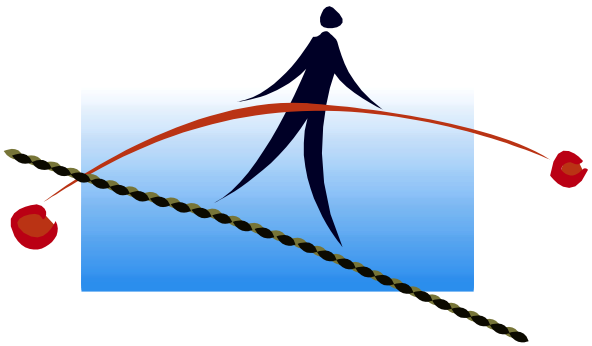
Objectives

At the end of this lecture student should be able to describe:

1. **Acid-Base balance**
2. **Normal range of Extracellular pH**
3. **Identify the body systems that control against Acid-Base Imbalance**
4. **Identify types of Acid-Base Imbalance**
5. **Symptoms and signs of Acid-Base imbalances**
6. **Treatments for Acid-Base imbalances**

What is Acid-base balance

- **Acid-base balance is a balance of H^+ concentration in ECF.**
- **To achieve homeostasis a balance between the intake or production of hydrogen ions and the net removal of hydrogen ions from the body.**



pH Review

- **pH = - log [H^+]**
- **If [H^+] is high, the solution is acidic; pH < 7**
- **If [H^+] is low, the solution is basic or alkaline ; pH > 7**

table 2.5 Hydrogen Ion Concentrations and pH

Grams of H^+ per Liter	pH	
0.00000000000001	14	
0.0000000000001	13	↑
0.000000000001	12	Increasingly basic
0.00000000001	11	
0.0000000001	10	
0.000000001	9	
0.00000001	8	
0.0000001	7	Neutral–neither acidic nor basic
0.000001	6	
0.00001	5	
0.0001	4	
0.001	3	
0.01	2	Increasingly acidic
0.1	1	
1.0	0	↓

An Acid

- **Molecules containing hydrogen atoms that can <u>release</u> (donate) hydrogen ions in solutions are referred to as an acid.**
- **<u>Strong acids</u>: completely dissociate (HCL, H_2SO_4)**
- **<u>Weak acid</u>: partially dissociate (H_2CO_3)**

A Base

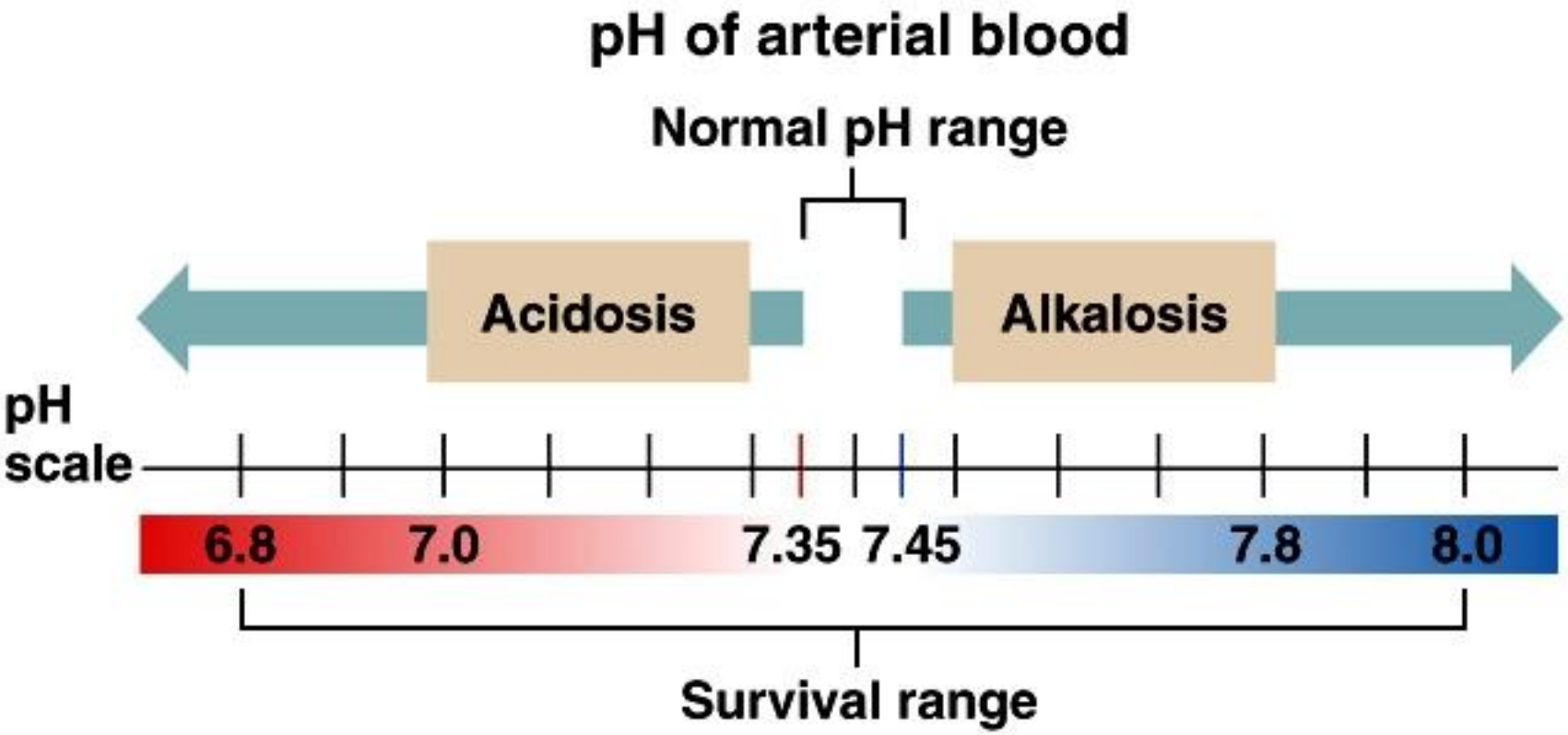
- **A base is an ion that can <u>accept</u> a hydrogen ion.**
- **An example of a base is is bicarbonate ion**
- **(HCO3)**

Extra cellular pH

- **Exctra-cellularr PH =7.4 (7.3 to 7.5)**
- **Homeostasis of pH is important for the function of body enzymes**
- **Acid-base balance can also affect electrolytes concentration (Na^+,K^+,Cl^-)**
- **Can also affect certain hormones**

Blood pH

- **Blood pH = 7.35 – 7.45**
- **Blood pH can be calculated by Henderson-Hasselbach equation**
- **PH = pKa + log10 [Base]**
  [Acid]
- **Acidosis= decrease in arterial pH (< 7.4) due to excess H+**
- **Alkalosis= an elevation in arterial PH (>7.4) due to excess base**
- **pH < 6.8 or > 8.0 death occurs**



Acid-Base Imbalances

- **pH< 7.35 acidosis**
- **pH > 7.45 alkalosis**
- **The body response to acid-base imbalance is called <u>compensation</u>**
- **Is complete if pH brought back within normal limits**
- **<u>Partial</u> compensation if range is still outside norms.**

System Compensation

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

Body produces more acids than bases

- **Acids take in with foods**
- **Acids produced by metabolism of lipids and proteins**
- **Cellular metabolism produces CO_2 (volatile acid)**
- **$CO_2 + H_20 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$**

Buffers

- **Buffers are substances that neutralize acids or bases**
- **Chemical reactions which reduce the effect of adding acid or base to a solution PH.**

How the Body defends against fluctuations in pH

- **Three Systems in the body:**

1. **Buffers in the blood**
2. **Breathing through the lungs**
3. **Excretion by the kidneys**

Blood Buffer

These buffer systems serve as a first line of defense against changes in the acid-base balance

- **Bicarbonate**
- **Protein**
- **Phosphate**
- **Haemoglobin**

Bicarbonate Buffer

- **Important extra cellular buffer**
- **HCO3=24-28 meq/ml**
- **Present in larger quantities**
- **Can be regulated by respiratory and renal**

Bicarbonate Buffer

- **Consist of: weak acid H_2CO_3 and Bicarbonate salt $NaHCO_3$**
- **HCO_3^- : H_2CO_3 Maintain at a ratio of 20:1**
- **pH = 6.1 + log $\frac{HCO_3}{0.03 \times PCO3}$**
- **If Acid is added**
  - **$H^+ + HCO_3 \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_2O$**
- **If Base is added**
  - **$NaOH + H_2CO_3 \leftrightarrow NaHCO_3 + H_2O$**

Phosphates & Intracellular Buffers

- **Phosphate is an intra and extracellular buffer**
- **Minor role compare to HCO_3 or HB**
- **Intra cellular buffers (proteins & phosphate) are needed because H does not cross PM**
- **Intracellular pH is more acidic (7.2)**

Proteins

- **Includes hemoglobin and plasma protein**
- **Acidic and basic amino acids in plasma and cell protein act as buffers**
  - **Carboxyl group gives up H^+**
  - **Amino Group accepts H^+**
- **Side chains that can buffer H^+ are present on 27 amino acids.**
- **Cannot be regulated physiological**

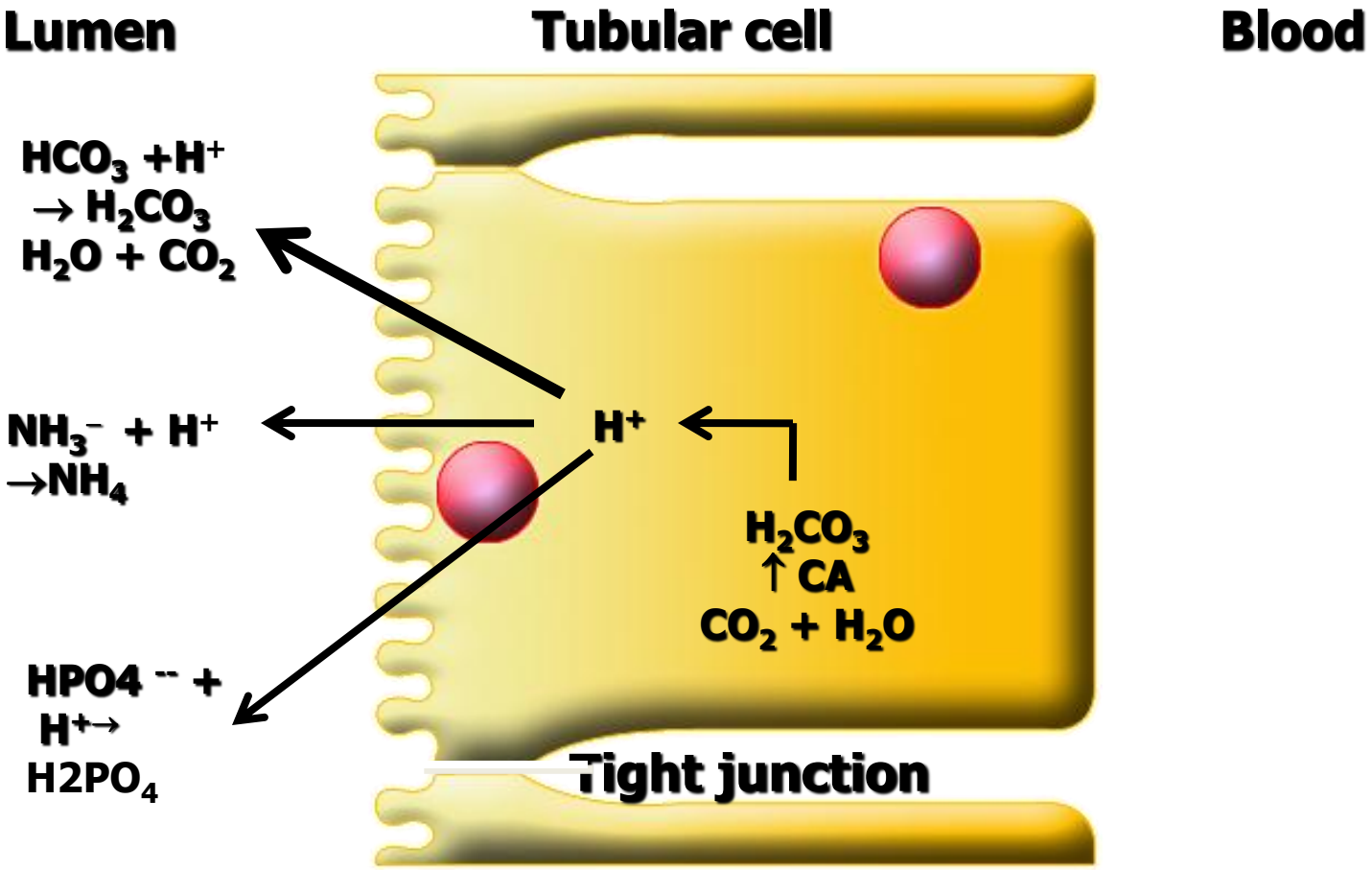
Respiratory regulation of pH

- **Maintain normal ECF pH by changing the rate and depth of breathing to maintain constant PCO_2 (volatile acid)**
- **Controlled by chemoreceptrs**
- **Respiratory doesn't affect fixed acids like lactic acid**
- **↑ in PCO2 → ↓ pH**

Kidney excretion

- **Can eliminate large amounts of acid by tubular secretion of H^+**
- **Can also excrete base by adjusting tubular reabsorption of HCO_3**
- **Can conserve and produce bicarbonate ions**
- **Kidney is the most effective regulator of pH**
- **If kidneys fail, pH balance fails**

Buffering of the excreted Hydrogen



Diagnosis of Acid-Base Imbalances

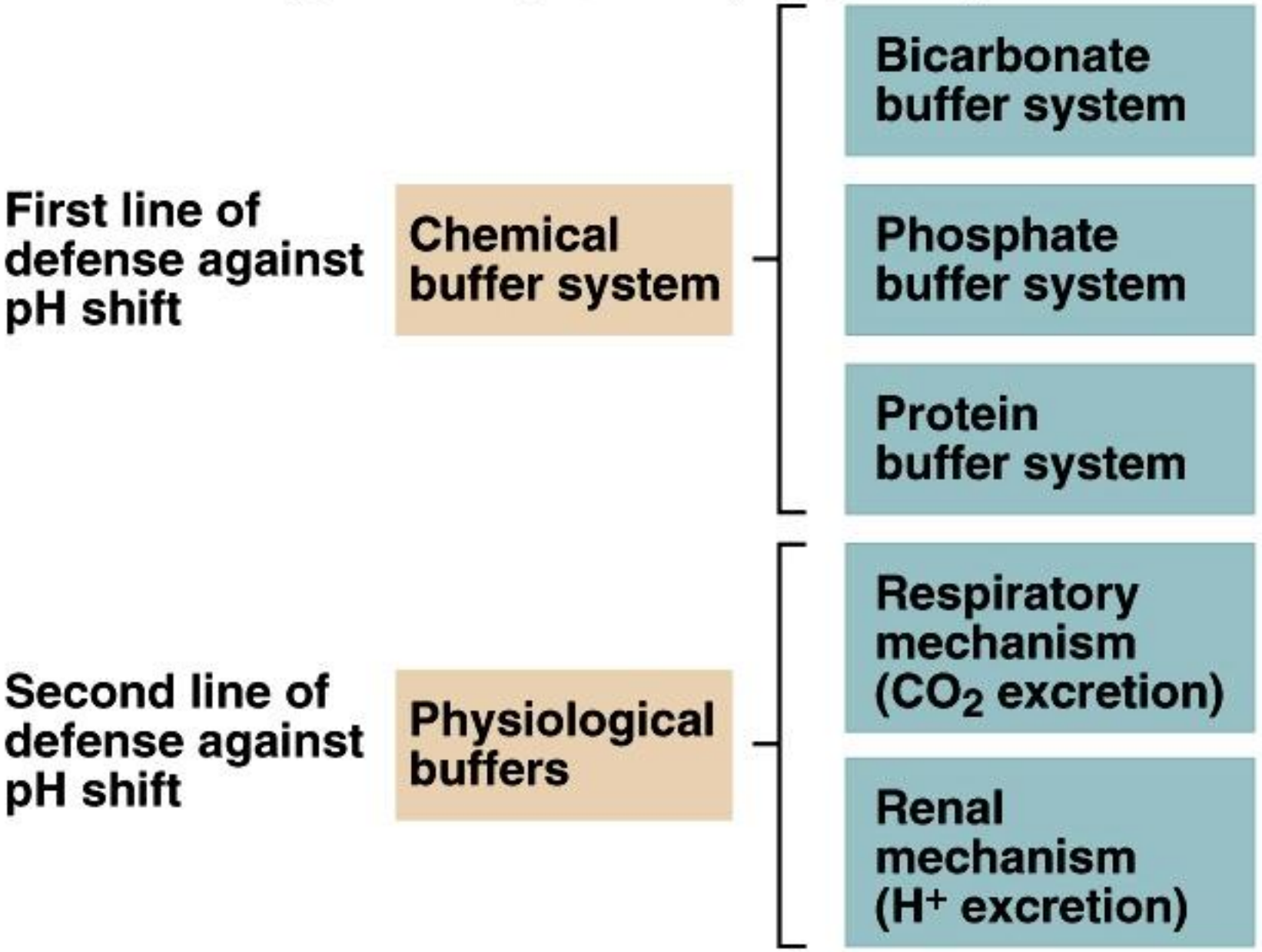
1. **pH low (acidosis) or high (alkalosis)**
2. **If pCO_2, is abnormal the problem is respiratory. If HCO_3^- is abnormal the problem is metabolic.**
3. **If pH is within the normal range, there is full compensation. If it is outside the normal range, the body is partially compensating for the problem.**

Acid-Base Imbalances

- **pH< 7.35 acidosis**
- **pH > 7.45 alkalosis**
- **The body response to acid-base imbalance is called compensation**
- **May be complete if brought back within normal limits**
- **Partial compensation if range is still outside norms.**

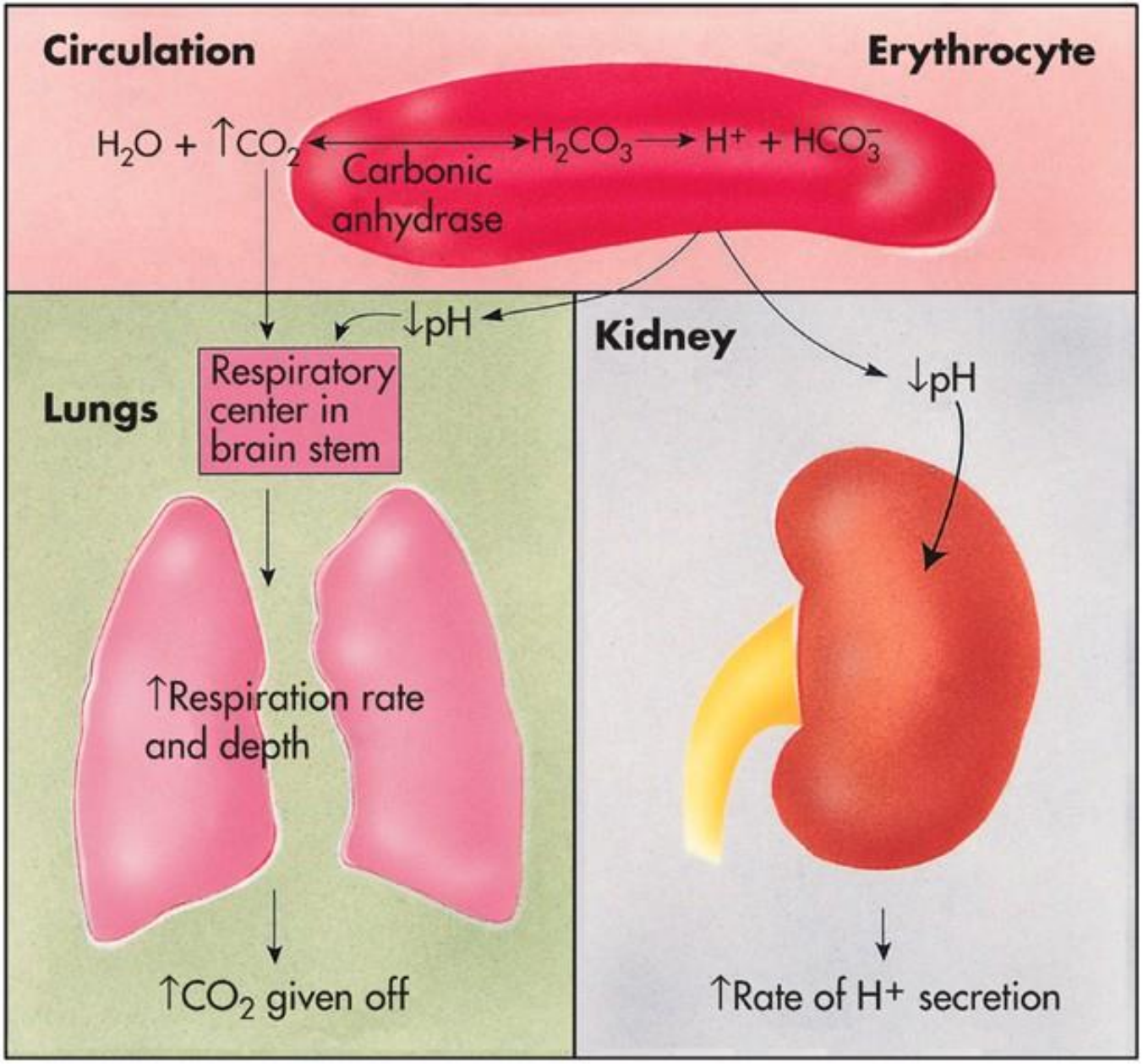
Compensation

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



Rates of correction

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



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Acid Base Imbalance

1. Acidosis

- **Low pH**
- **Metabolic casuses**
- **Respiratoy casuses**

2. Alkalosis

- **High pH**
- **Metabolic casuses**
- **Respiratoy casuses**

There are 4 Types of Acid-base Imbalances

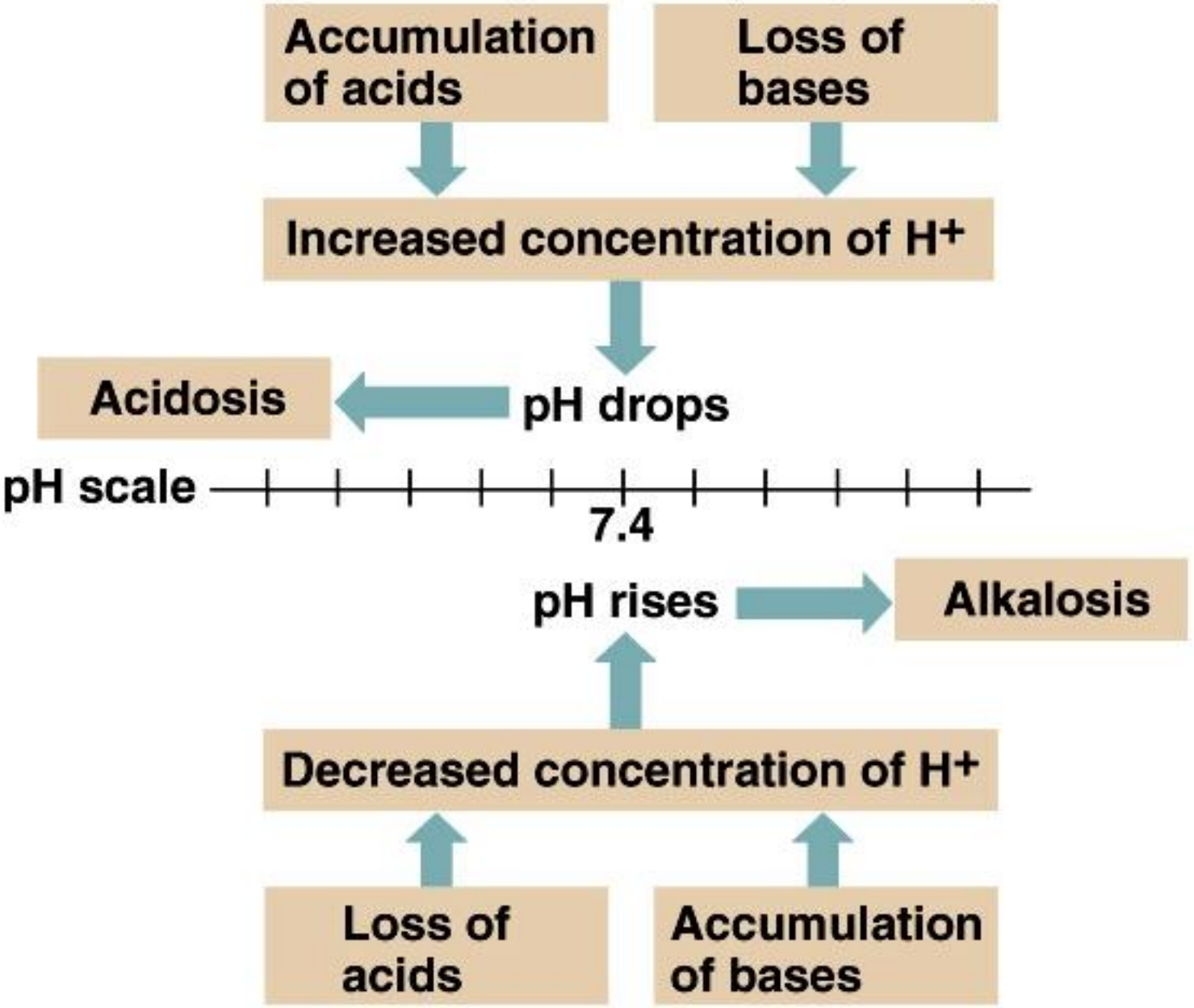
1. **Respiratory Alkalosis**
2. **Respiratory Acidosis**
3. **Metabolic Alkalosis**
4. **Metabolic Acidosis**

Acidosis

- **Principal effect of acidosis is depression of the CNS through ↓ in synaptic transmission.**
- **Generalized weakness**
- **Severe acidosis causes**
  - **Disorientation**
  - **coma**
  - **death**

Alkalosis

- **Alkalosis causes over excitability of the central and peripheral nervous systems.**
- **Numbness**
- **Lightheadedness**
- **It can cause :**
  - **Nervousness**
  - **muscle spasms or tetany**
  - **Convulsions**
  - **Loss of consciousness**
  - **Death**



Respiratory Acidosis

Respiratory acidosis

- **Low pH**
- **High PCO_2 (Hypercapnia)**
  - **Depressed ventilation**
- **HCO_3 = N**

Causes of Respiratory Acidosis

- **Chronic conditions:**
  - **Depression of respiratory center in brain that controls breathing rate – drugs or head trauma**
  - **Paralysis of respiratory or chest muscles**
  - **Emphysema**
- **Acute conditons:**
  - **Adult Respiratory Distress Syndrome**
  - **Pulmonary edema**
  - **Pneumothorax**

Signs and Symptoms of Respiratory Acidosis

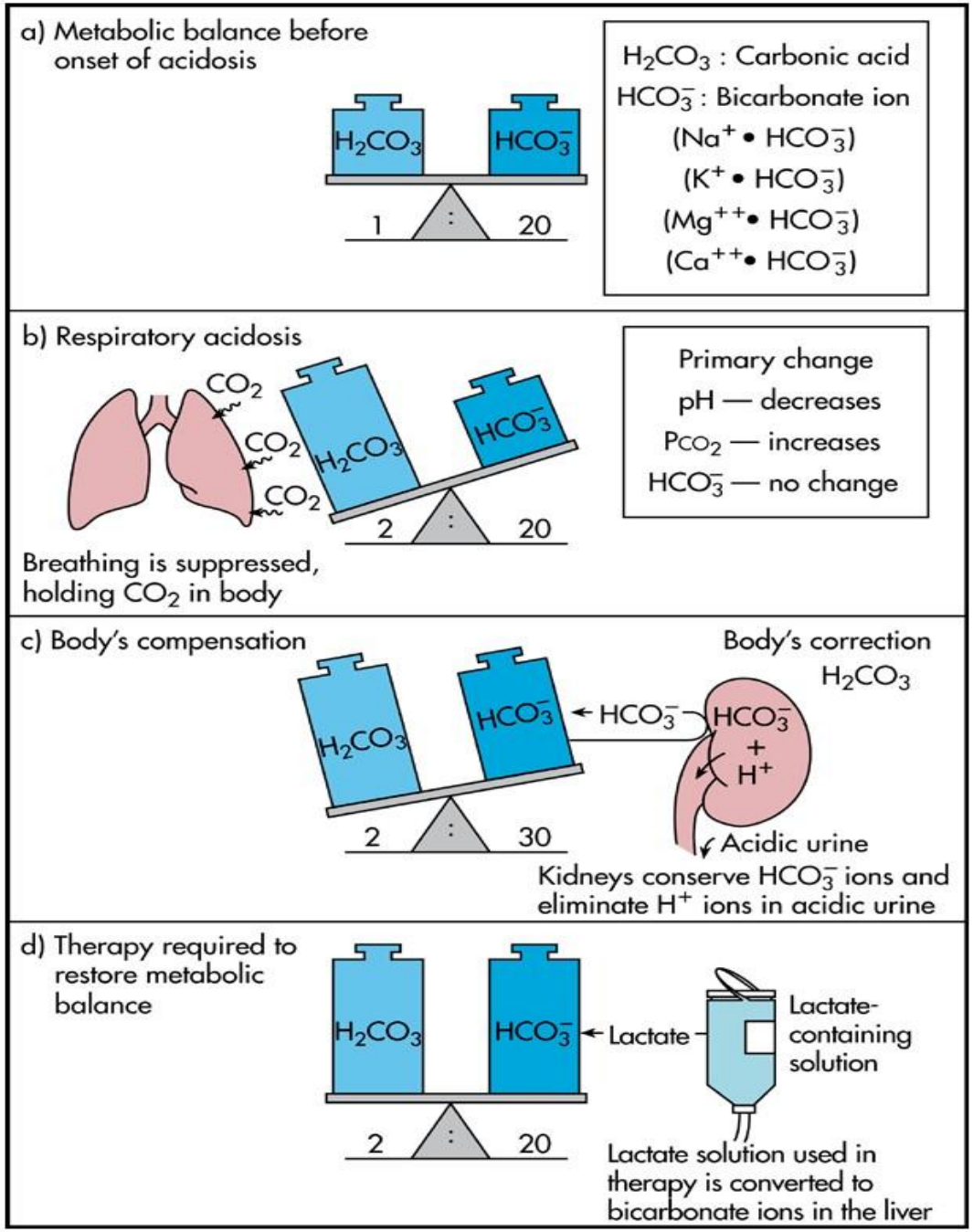
- **Breathlessness**
- **Restlessness**
- **Lethargy and disorientation**
- **Tremors, convulsions, coma**
- **Respiratory rate rapid, then gradually depressed**
- **Skin warm and flushed due to vasodilation caused by excess CO_2**

Compensation for Respiratory Acidosis

- **Kidneys eliminate hydrogen ion and retain bicarbonate ion**
- **Blood picture**
  - **pH = N**
  - **PCO_2 = High**
  - **HCO_3 = High compensation**
- **Low Urine HCO_3**

Treatment of Respiratory Acidosis

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



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Respiratory Alkalosis

Respiratory alkalosis

- **high pH**
- **low PCO_2**
  - **hyper ventilation**
    - **Hysterical**
    - **pneumonia**
- **HCO_3 normal**

Respiratory Alkalosis

- **PCO_2 less than 35 mm Hg (hypocapnea)**
- **Primary cause is hyperventilation**

Respiratory Alkalosis

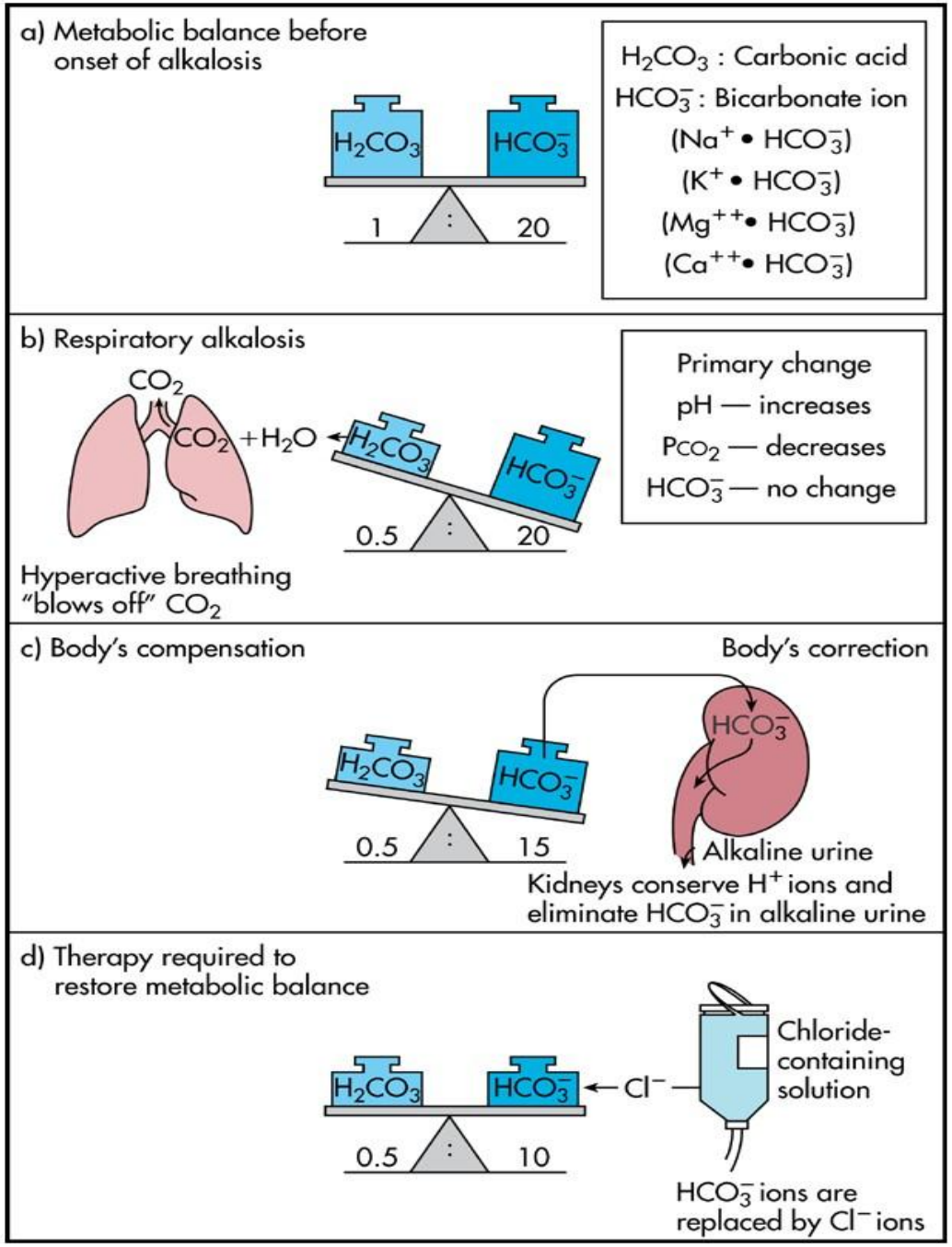
- **Oxygen deficiency at high altitudes**
- **Pulmonary disease and Congestive heart failure – caused by hypoxia**
- **Acute anxiety**
- **Fever, anemia**
- **Early salicylate intoxication**
- **Cirrhosis**
- **Gram-negative sepsis**

Compensation of Respiratory Alkalosis

- **Kidneys conserve hydrogen ion**
- **Excrete more bicarbonate ion**
- **Blood picture**
  - **pH = N**
  - **PCO_2 = Low**
  - **HCO_3 = Low compensation**
- **High urine HCO_3**

Treatment of Respiratory Alkalosis

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



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Metabolic Acidosis

Metabolic Acidosis

- **Low pH**
- **Low HCO_3**
  - **Production of Lactic acid (anerobic metabolism**
  - **Production of ketoacid (diabetes)**
  - **Excessive loss of alkali (diarrhoea)**
  - **Renal failure**
- **PCO_2 = normal**

Metabolic Acidosis

- **Bicarbonate deficit < 22mEq/L**
- **Causes:**
  - **Loss of bicarbonate through diarrhea or renal dysfunction**
  - **Accumulation of acids (lactic acid or ketones)**
  - **Failure of kidneys to excrete H+**

Symptoms of Metabolic Acidosis

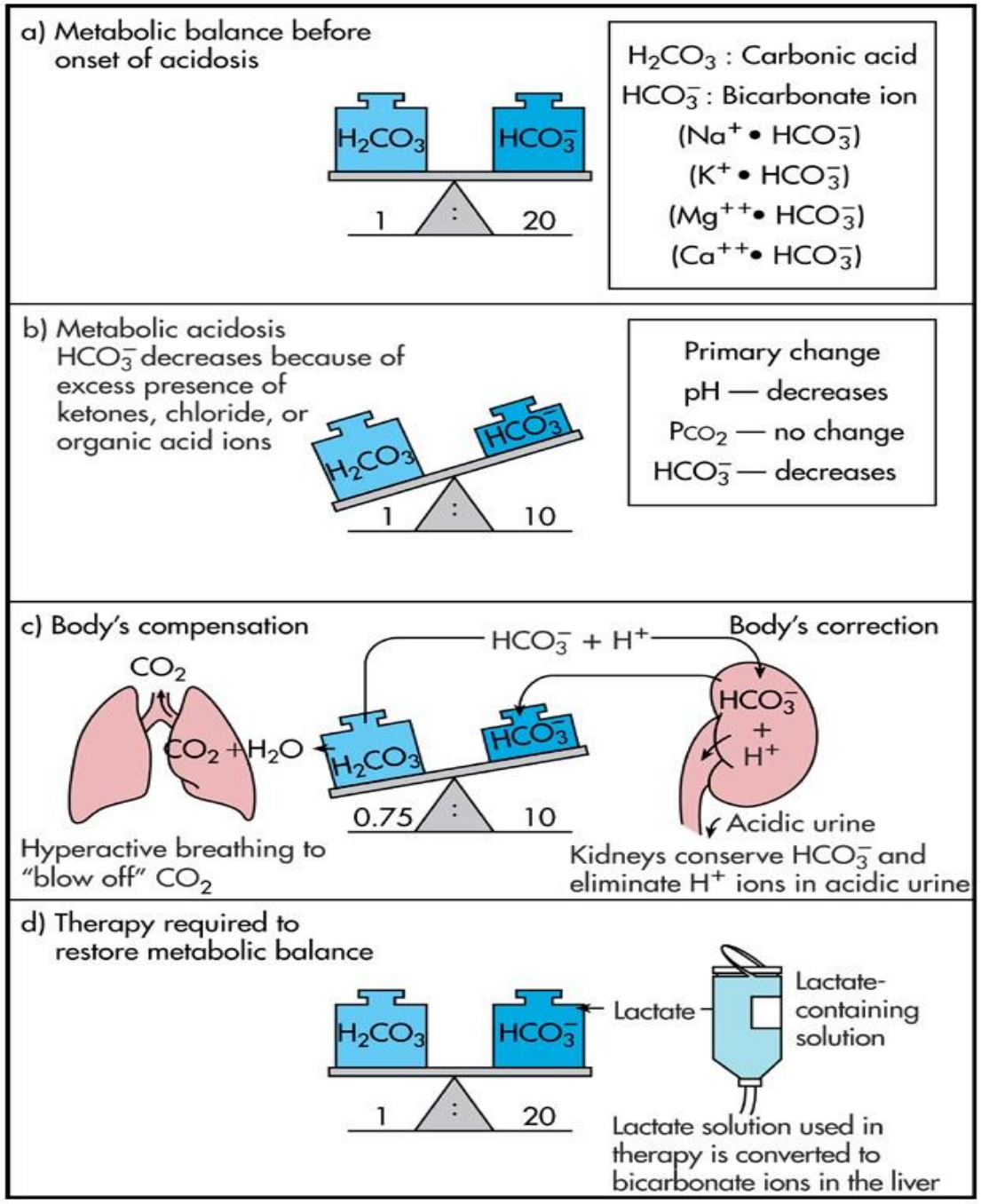
- **Headache, lethargy**
- **Nausea, vomiting, diarrhea**
- **Coma**
- **Death**

Compensation for Metabolic Acidosis

- **Stimulation of ventilation (hyperventilation) $\rightarrow \downarrow PCO_2 \rightarrow \uparrow$ pH back to normal value**
- **Renal excretion of hydrogen ions if possible**
- **K^+ exchanges with excess H^+ in ECF (H^+ into cells, K^+ out of cells)**
- **Blood picture**
  - **pH = ~N**
  - **HCO_3 = Low**
  - **PCO_2 = Low compensation**

Treatment of Metabolic Acidosis

- **IV lactate solution**



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Metabolic Alkalosis

Metabolic Alkalosis

- **high pH**
- **High HCO_3**
  - **Loss of gastric acid (vomiting)**
  - **Excessive intake of alkali (antiacid)**
- **PCO_2 = Normal**

Metabolic Alkalosis

- **Bicarbonate > 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**

Compensation for Metabolic Alkalosis

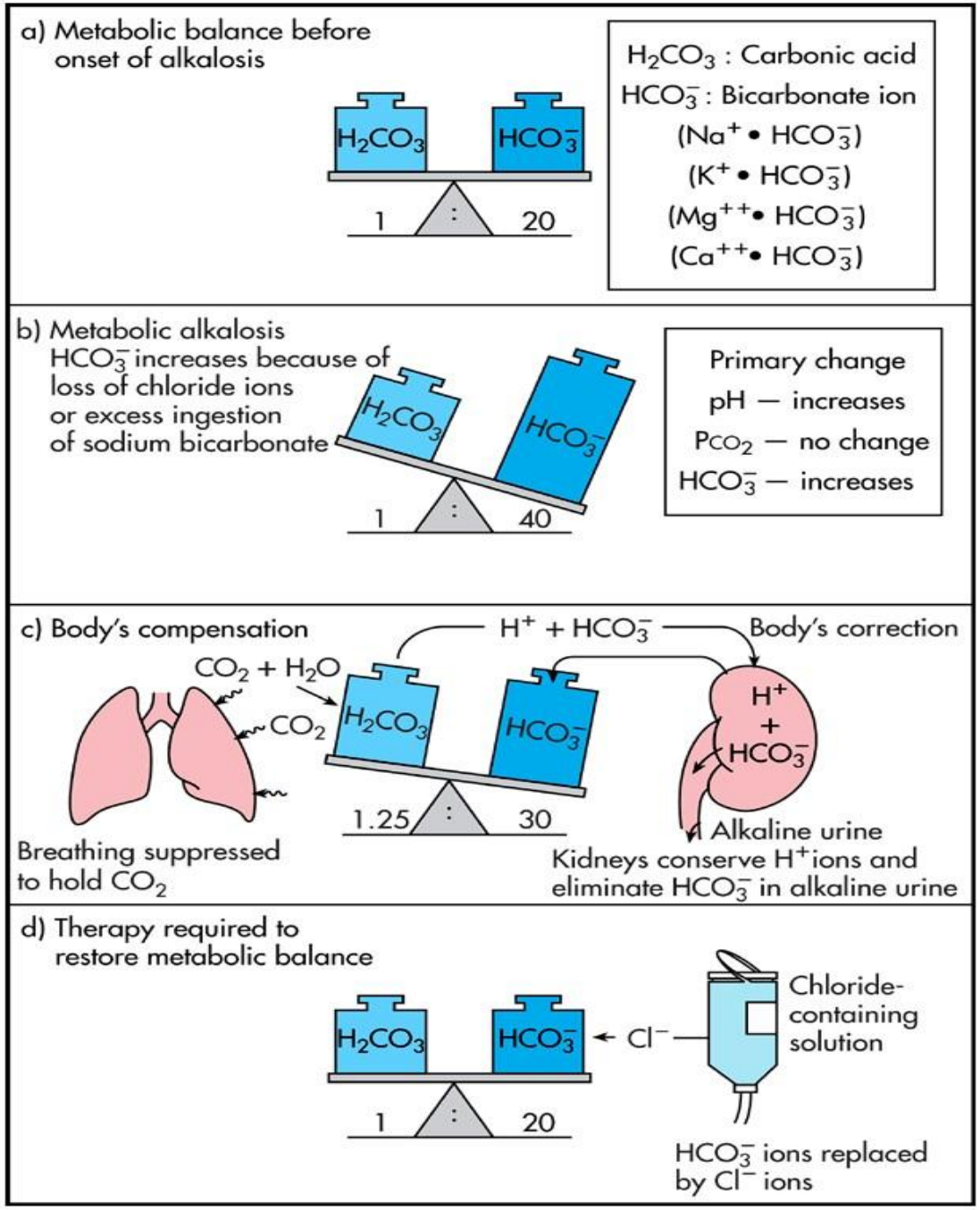
- **Correction**
  - **depress ventilation $\rightarrow \uparrow$ blood $PCO_2 \rightarrow \downarrow$ pH back to normal value (limited by hypoxia)**
- **Alkalosis most commonly occurs with renal dysfunction, so can't count on kidneys**
- **Blood picture**
  - **pH = ~N**
  - **HCO_3 = High**
  - **PCO_2 = High compensation**

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**



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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**
  - **HCO_3^- = 20 mEq / L (22 - 26)**
  - **pCO_2 = 32 mm Hg (35 - 45)**

Diagnosis

- **Metabolic acidosis**
- **With compensation**

Summary

- **Acidosis**

	Abnormalities			
pH	⇓	⇔	⇓	⇔
PCO_2	⇑	⇑	⇔	⇓
HCO_3	⇔	⇑	⇓	⇓
Type	**Resp**	**Resp**	**Metab**	**Metab**
Correction	**No**	**Yes Metab**	**No**	**Yes Resp**

Summary

- **Alkalosis**

	Abnormalities			
pH	⇑	⇔	⇑	⇔
PCO_2	⇓	⇓	⇔	⇑
HCO_3	⇔	⇓	⇑	⇑
Type	**Resp**	**Resp**	**Metab**	**Metab**
Correction	**No**	**Yes Metab**	**No**	**Yes Resp**