Acid Base System

Dr Sitelbanat

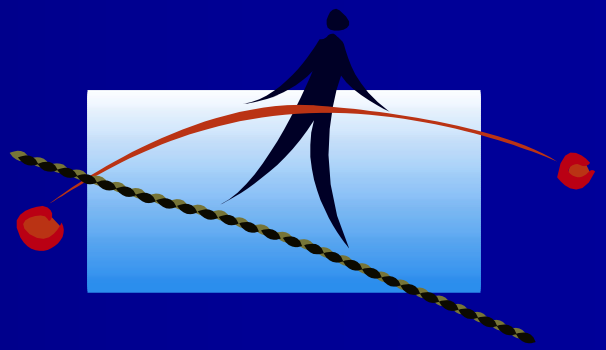
Objectives

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	↑ Increasingly basic
0.0000000000001	13	
0.000000000001	12	
0.00000000001	11	
0.0000000001	10	
0.000000001	9	
0.00000001	8	Neutral–neither acidic nor basic
0.0000001	7	
0.000001	6	
0.00001	5	
0.0001	4	
0.001	3	Increasingly acidic
0.01	2	
0.1	1	↓
1.0	0	

An Acid

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

A Base

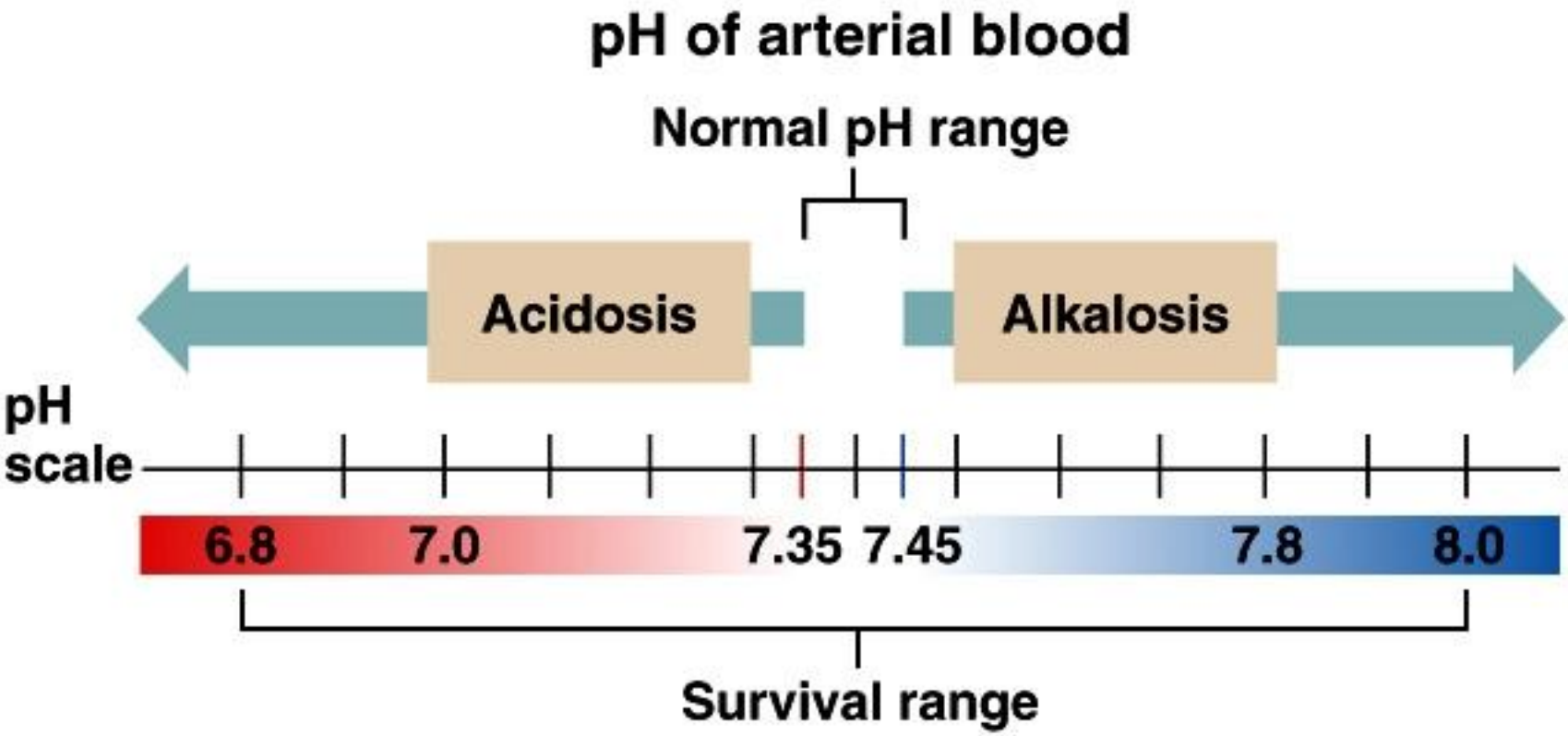
- A base is an ion that can accept a hydrogen ion.
- An example of a base is is bicarbonate ion
- (HCO3)

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 the function of certain hormones

Blood pH

- Blood pH = 7.35 – 7.45
- Blood pH can be calculated by Henderson-Hasselbach equation
- $PH = pKa + \log_{10} \frac{[Base]}{[Acid]}$
- 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 not compatible with life



Acid-Base Imbalances

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

Normally our 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
- HCO_3=24-28 meq/ml
- Present in larger quantities
- Can be regulated by respiratory and renal system

Bicarbonate Buffer

- Consist of: weak acid H_2CO_3 and Bicarbonate salt $NaHCO_3$
- HCO_3^- : H_2CO_3 is maintained at a ratio of 20:1
- pH of bicarbonate = 6.1 + log $\frac{HCO_3}{0.03 \times PCO2}$
- 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 physiologicaly

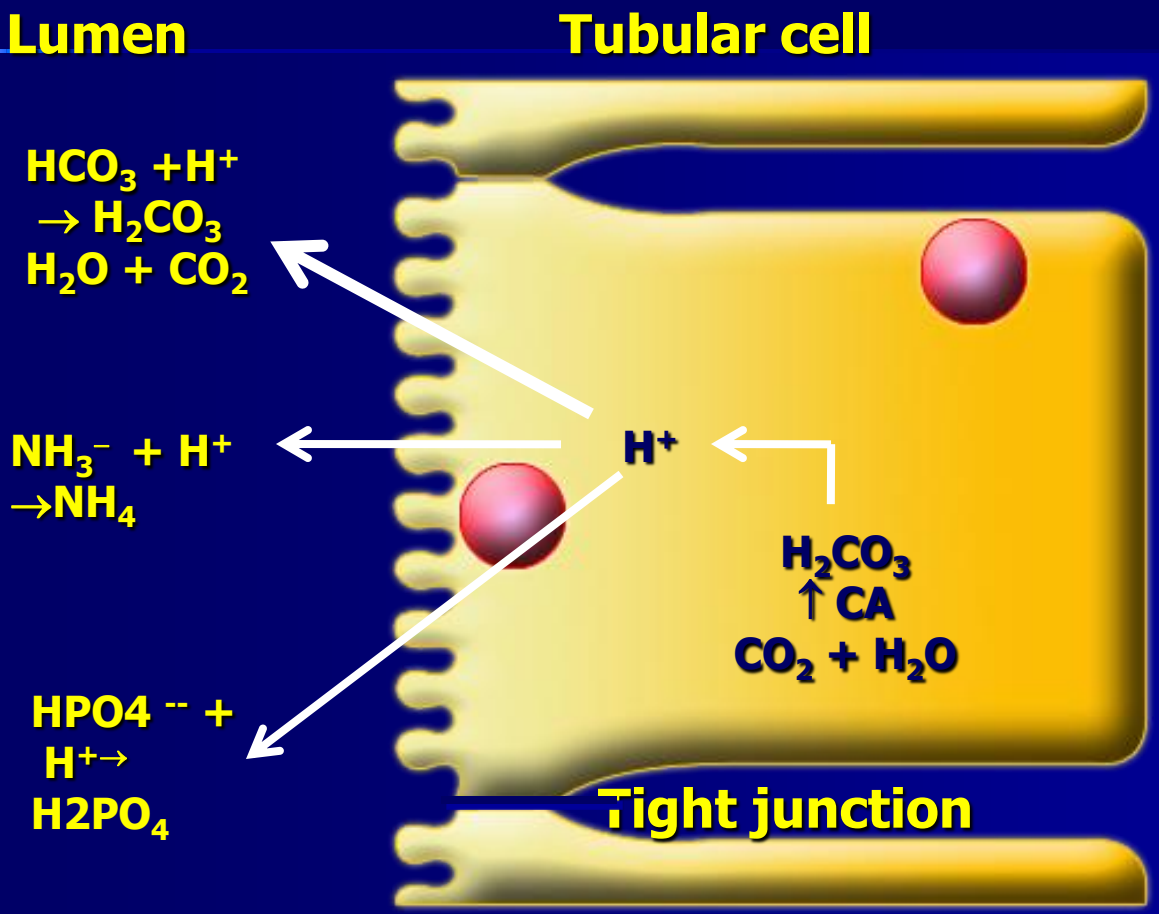
Respiratory regulation of pH

- Maintain normal ECF pH by changing the rate and depth of breathing to maintain constant PCO_2 (volatile acid)
- Controlled by chemoreceptrs
- Respiratory sys 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 new bicarbonate ions
- Kidney is the most effective regulator of pH
- If kidneys fail, pH balance fails

Buffering of the excreted Hydrogen

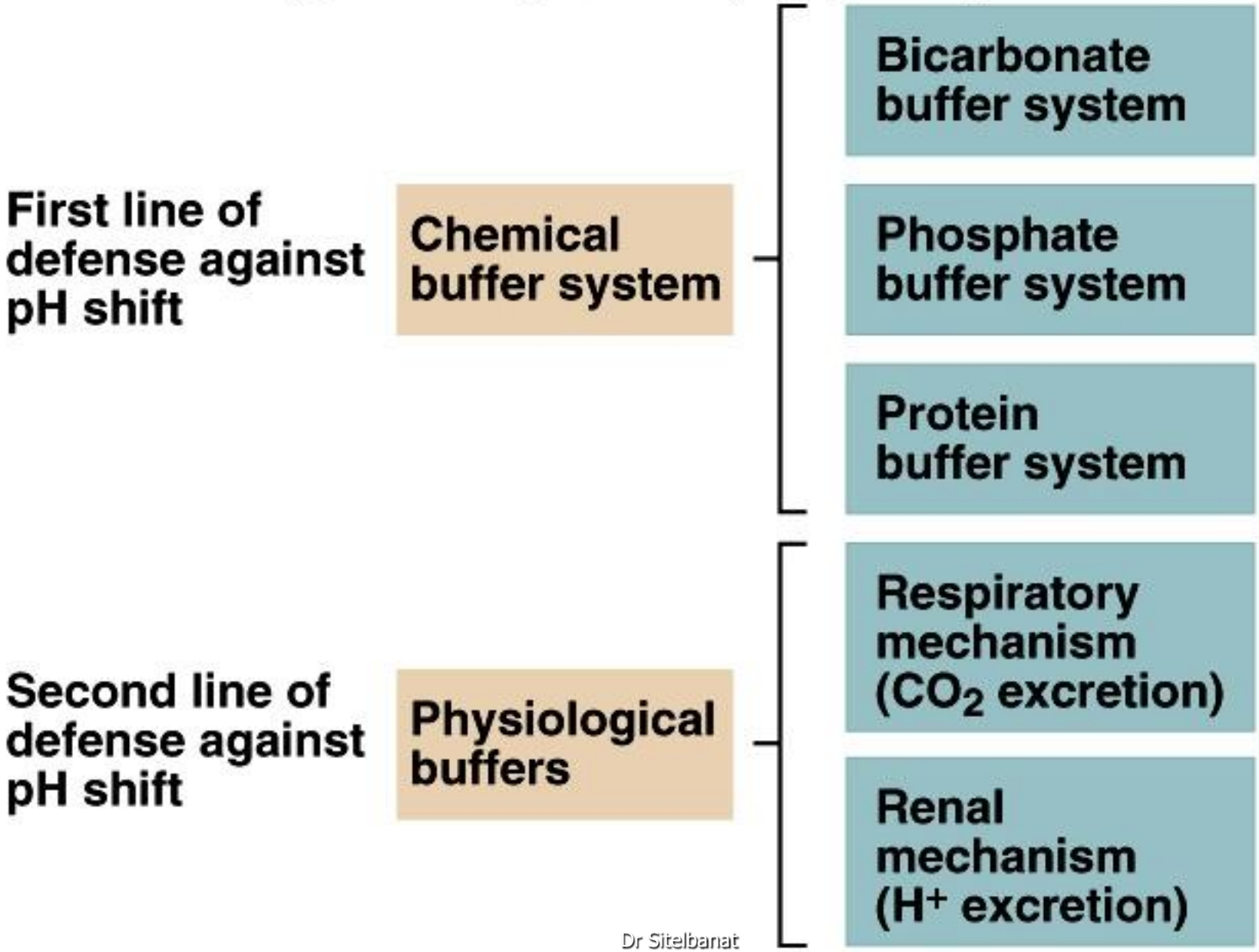


Diagnosis of Acid-Base Imbalances

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.

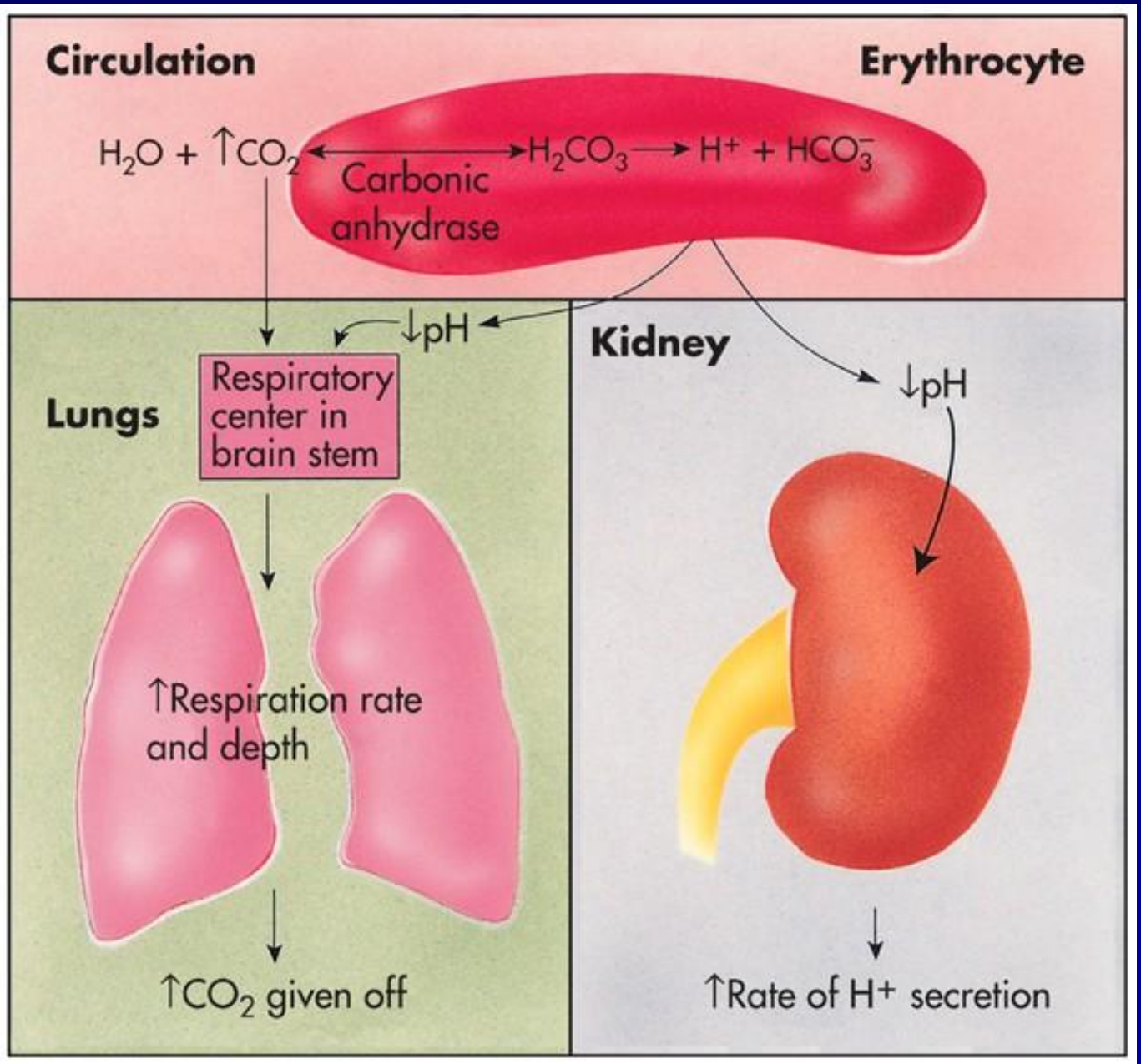
Compensation

- 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



From Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 5, St Louis, 2003, Mosby.

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

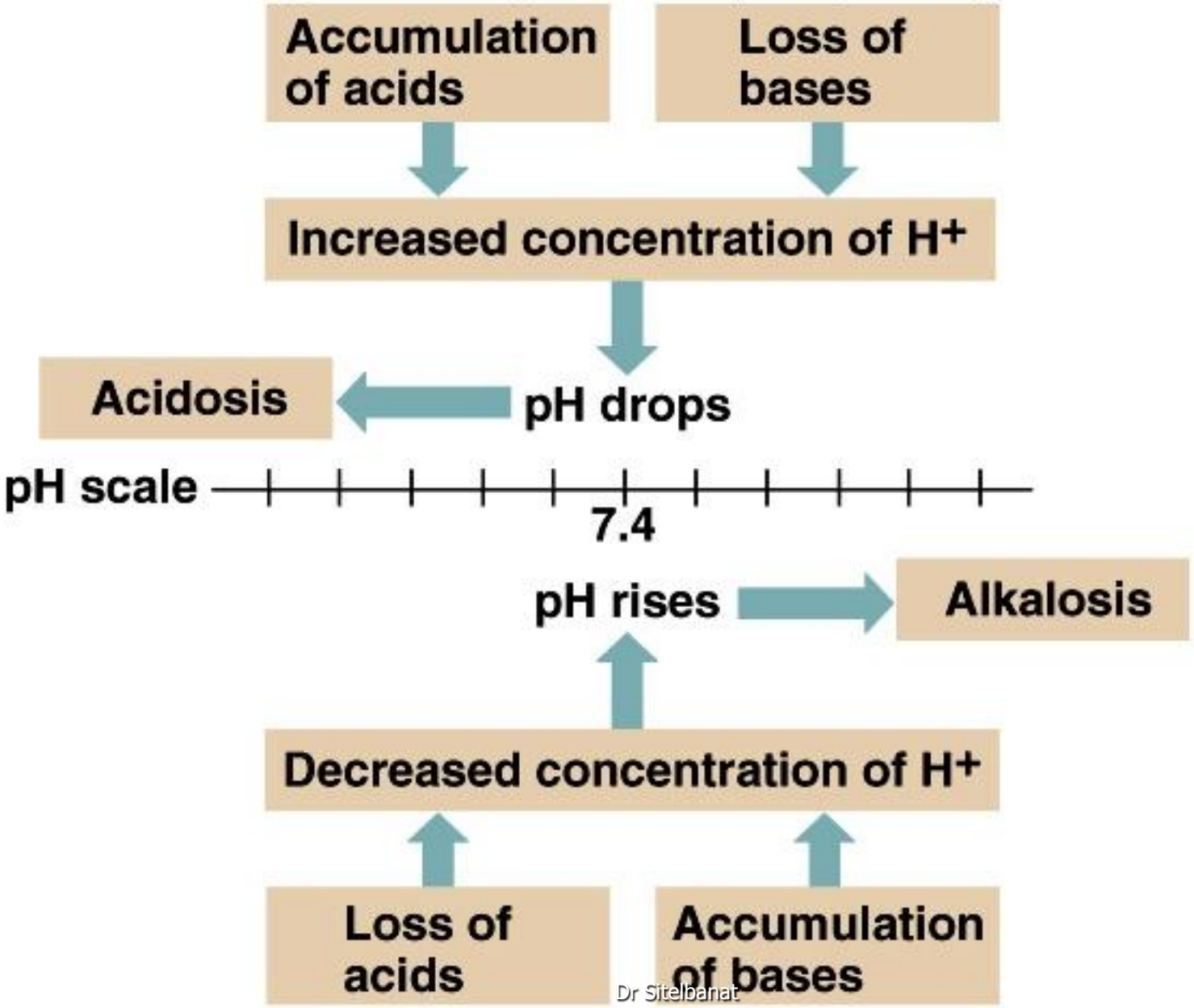
1. Respiratory Alkalosis
2. Respiratory Acidosis
3. Metabolic Alkalosis
4. Metabolic Acidosis

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 tetanic
  - 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

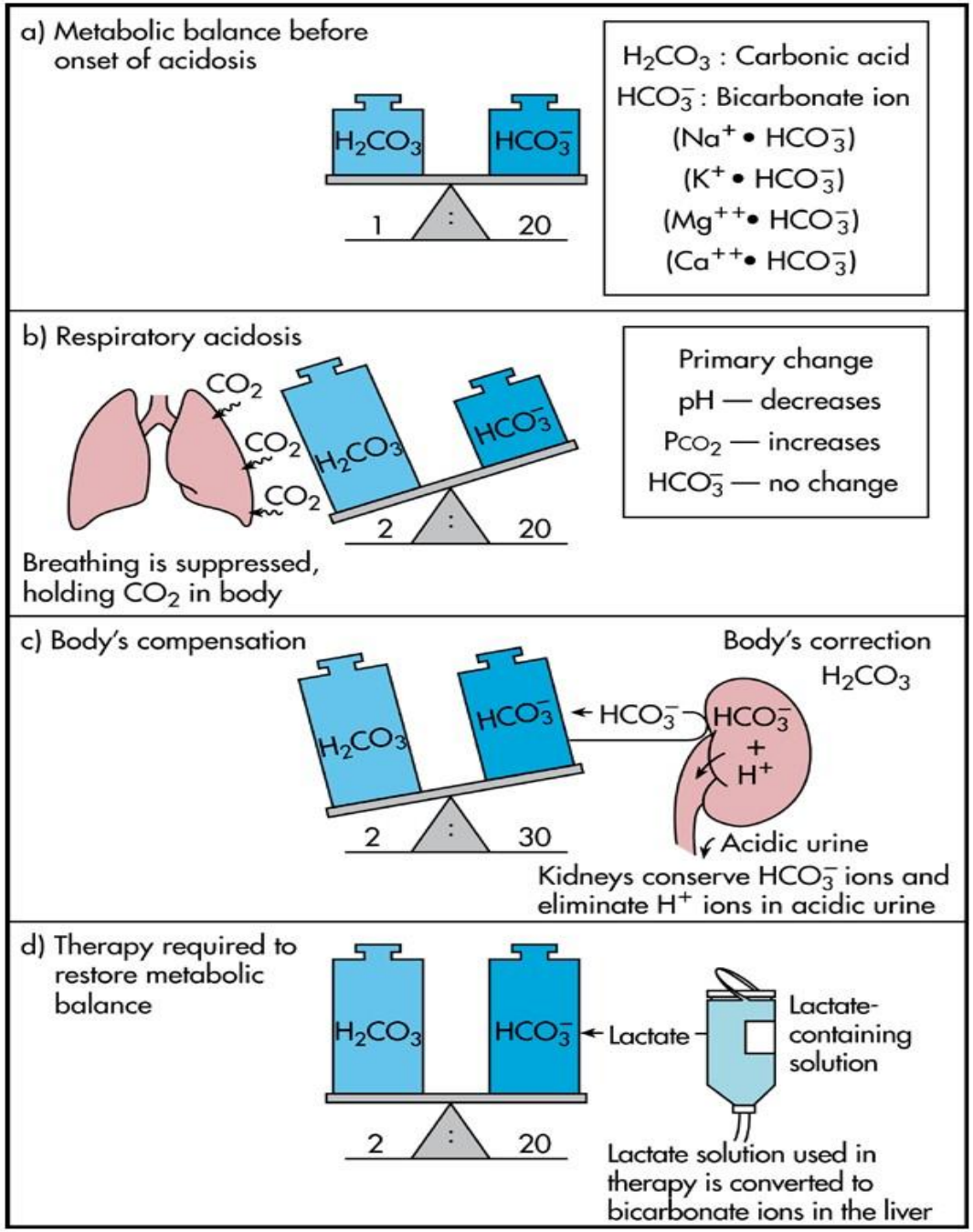
- Breathlessness
- Restlessness
- Lethargy and disorientation
- Tremors, convulsions, coma
- Respiratory rate rapid, then gradually depressed
- Skin warm and flushed due to vasodilation caused by excess CO_2

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

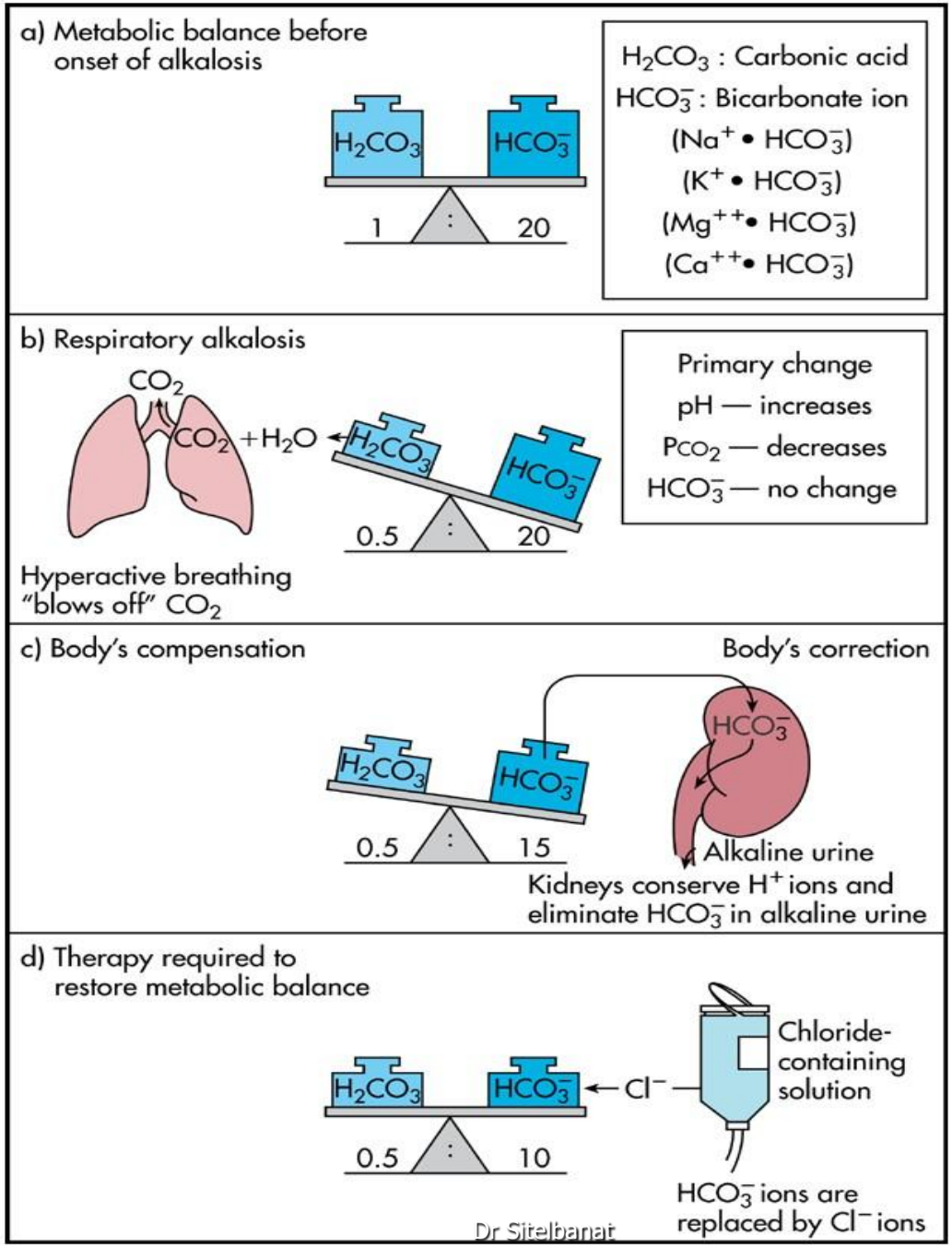
- Oxygen deficiency at high altitudes
- Pulmonary disease and Congestive heart failure – caused by hypoxia
- Acute anxiety
- Fever, anemia
- Early salicylate intoxication
- Cirrhosis
- Gram-negative sepsis

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

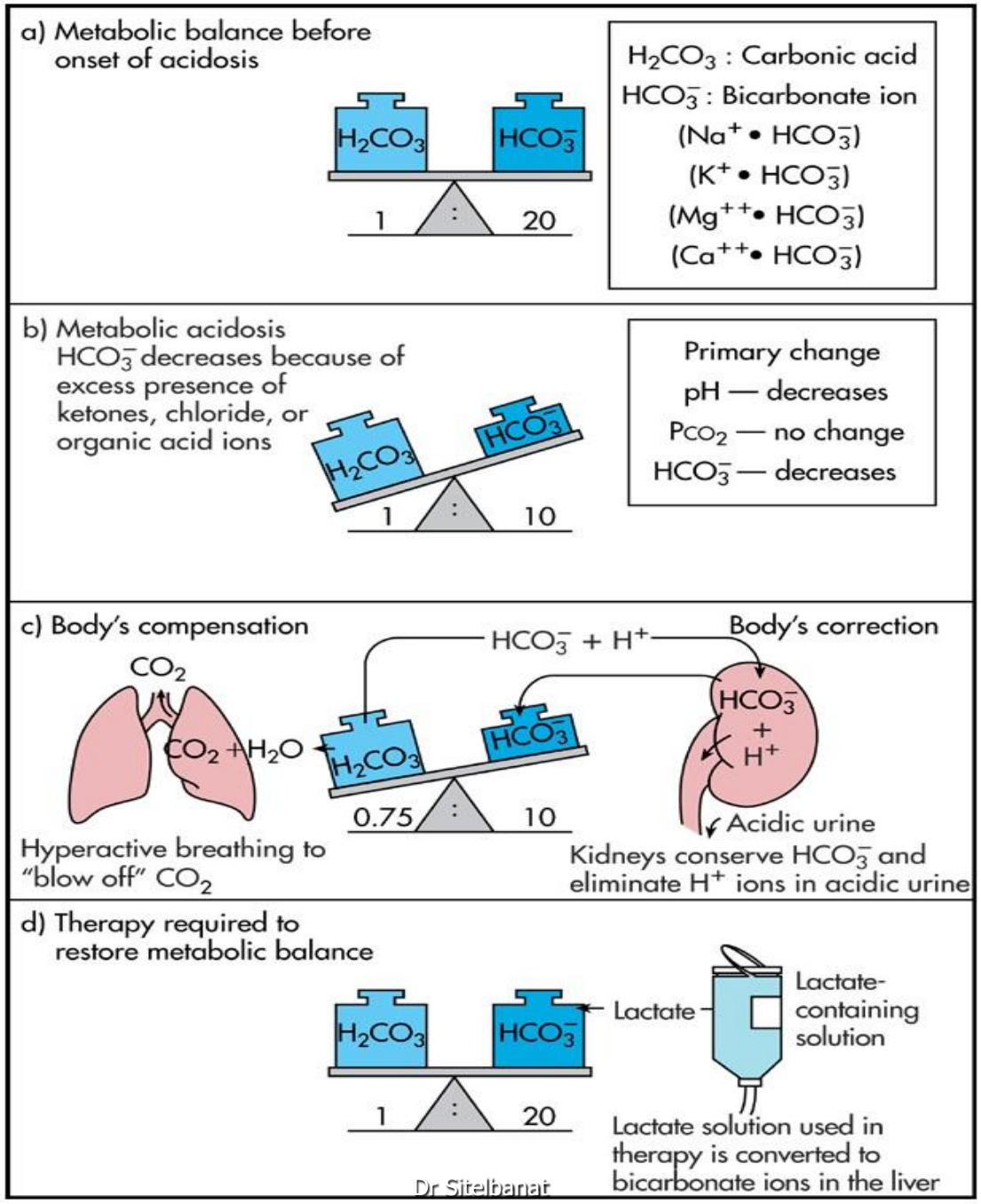
- Headache, lethargy
- Nausea, vomiting, diarrhea
- Coma
- Death

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 due to 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
  - Heavy ingestion of antacids

Compensation for Metabolic Alkalosis

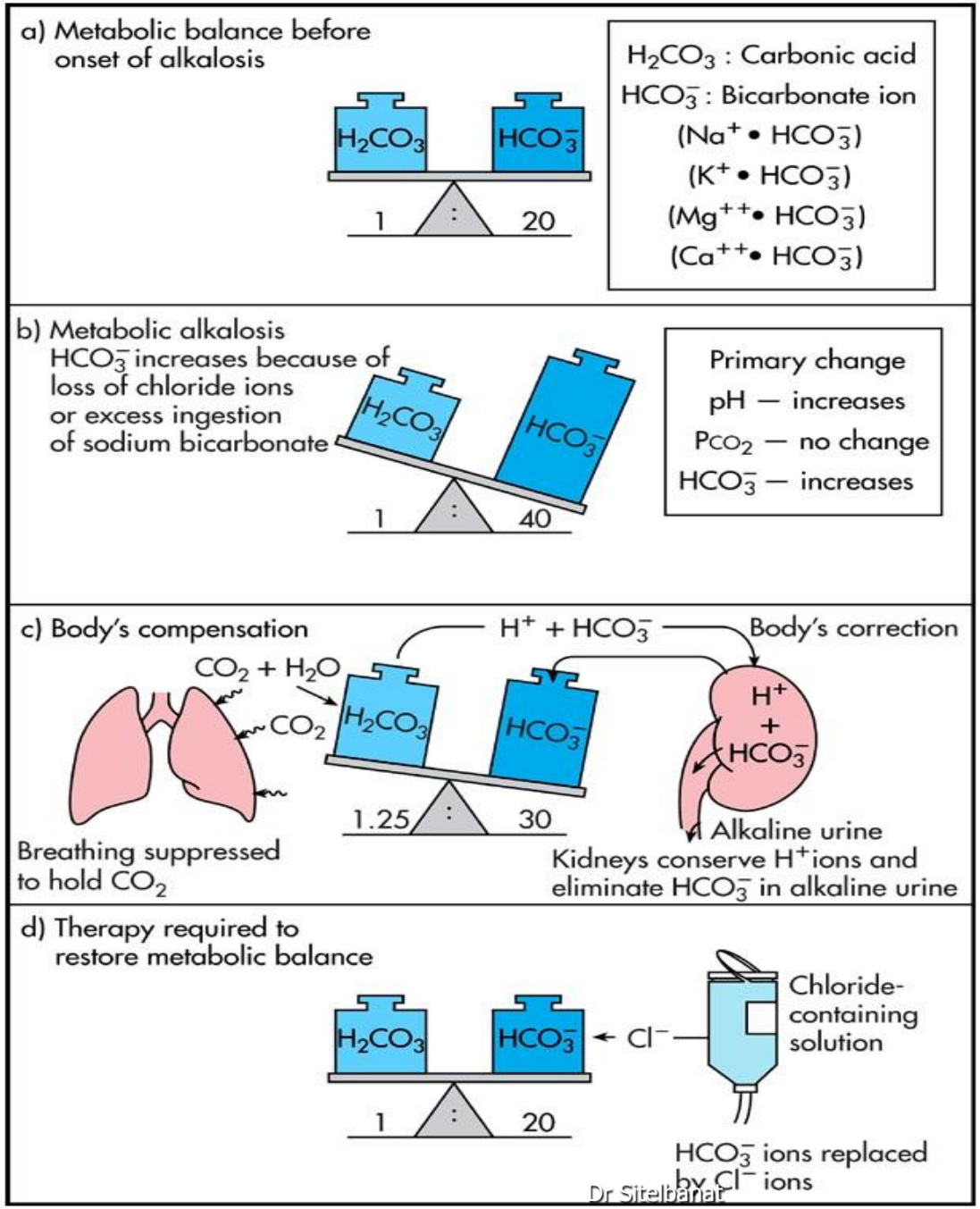
- **Correction**
  - **depress ventilation → ↑ blood PCO_2 → ↓ pH back to normal value (limited by hypoxia)**
- **Alkalosis most commonly occurs with renal dysfunction, so can't count on kidneys**
- **Blood picture**
  - **pH = ~N**
  - **HCO_3 = High**
  - **PCO_2 = High due to compensation**

Symptoms of Metabolic Alkalosis

- Respiration is 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 partial 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**