First year MBBS

- FOUNDATION MODULE
- SUBJECT:BIOCHEMISTRY
- DATE : 16-3-2021
- TIMINGS : 9AM TO 10AM
- BY DR SAIMA SHAHEEN

Buffers: Chemistry of acids and bases (Acidosis and Alkalosis)

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- Acids are H^+ donors.
- Bases are H^+ acceptors, or give up OH^- in solution.
- Acids and bases can be:
  - Strong – dissociate completely in solution
    - HCl, NaOH
  - Weak – dissociate only partially in solution
    - Lactic acid, carbonic acid

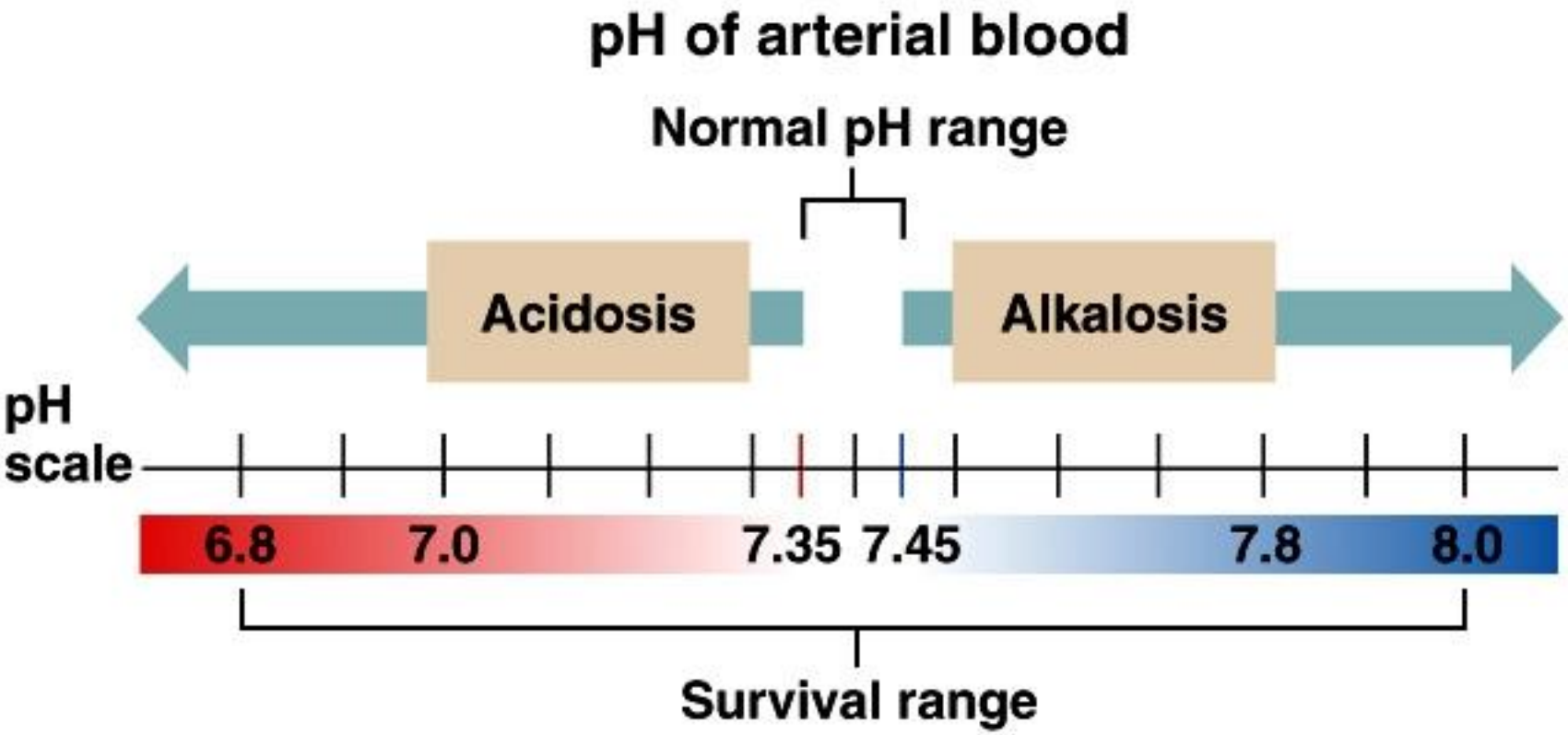
Model	Definition of Acid	Definition of Base
Arrhenius	H^+ producer	OH^- producer
Bronsted-Lowry	H^+ donor	H^+ acceptor
Lewis	Electron-pair acceptor	Electron-pair donor

pH Review

- pH = - log [H^+]
- H^+ is really a proton
- Range is from 0 - 14
- If [H^+] is high, the solution is acidic; pH < 7
- If [H^+] is low, the solution is basic or alkaline ; pH > 7

The Body and pH

- Homeostasis of pH is tightly controlled
- Blood = 7.35 – 7.45
- < 6.8 or > 8.0 death occurs
- Acidosis (acidemia) below 7.35
- Alkalosis (alkalemia) above 7.45



Small changes in pH can produce major disturbances

- Most enzymes function only with narrow pH ranges
- Acid-base balance can also affect electrolytes (Na^+, K^+, Cl^-)
- Can also affect hormones

The body produces more acids than bases

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

Control of Acids

1. Buffer systems

*A buffer solution is an aqueous solution consisting of a mixture of a weak acid and its conjugate base, or vice versa. Its pH changes very little when a small amount of strong acid or base is added to it.

*Take up H+ or release H+ as conditions change

*Buffer pairs – weak acid and a base

*Exchange a strong acid or base for a weak one

*Results in a much smaller pH change

Body buffers

- The three major buffer systems of our body are
- 1)**carbonic acid bicarbonate buffer system**
- 2) **phosphate buffer system** and
- 3)**protein buffer system**.

Bicarbonate buffer

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

$HCl + NaHCO_3 \leftrightarrow H_2CO_3 + NaCl$

$NaOH + H_2CO_3 \leftrightarrow NaHCO_3 + H_2O$

Phosphate buffer

- Major intracellular buffer
- $H^+ + HPO_4^{2-} \leftrightarrow H_2PO4^-$

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

Protein Buffers

- Includes hemoglobin, works in blood.
- Carboxyl group gives up H^+
- Amino Group accepts H^+
- Side chains that can buffer H^+ are present on most of the amino acids.

2. Respiratory mechanisms

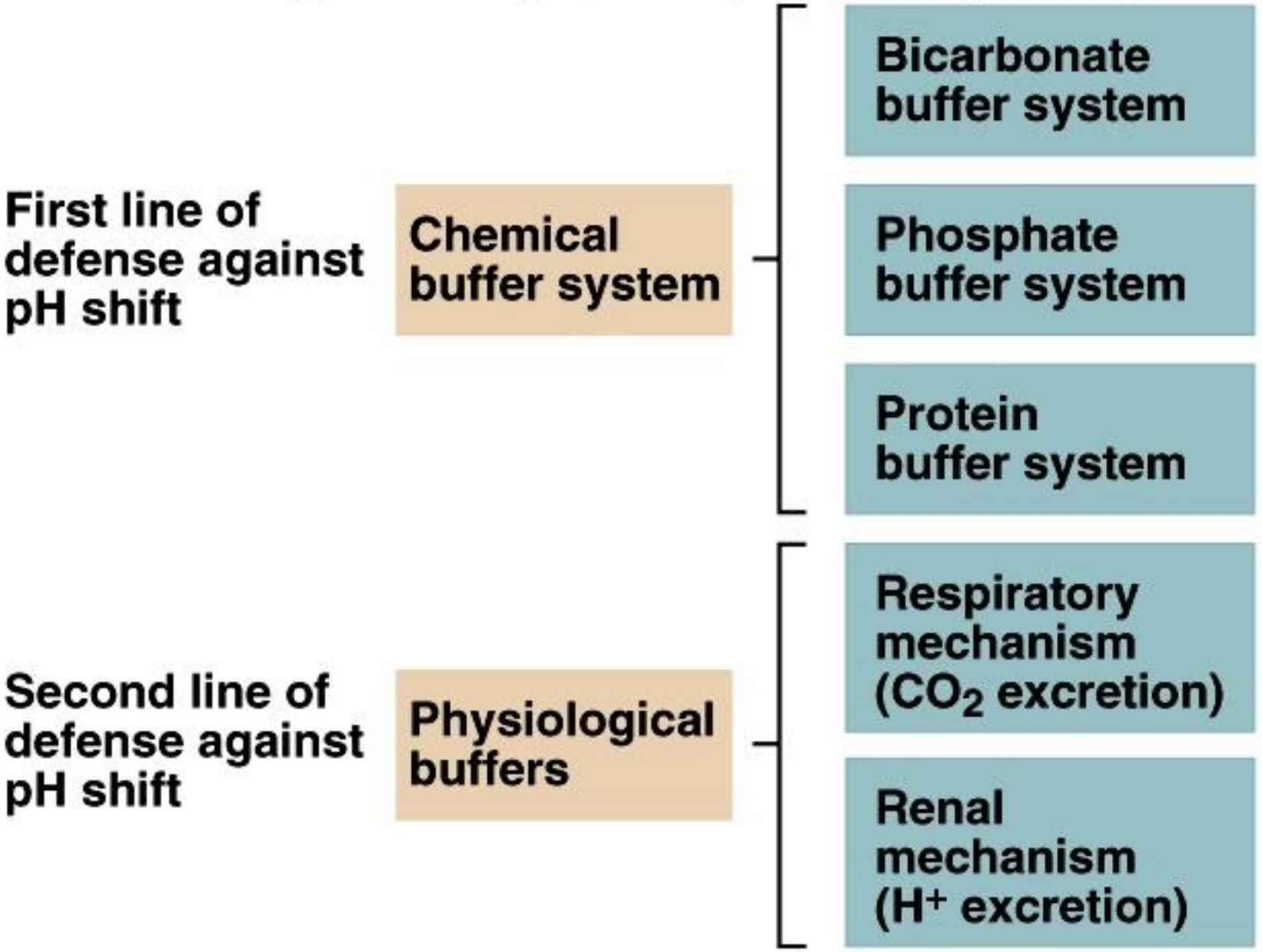
- Exhalation of carbon dioxide
- Powerful, but only works with **volatile acids**
- Doesn't affect **fixed acids** like lactic acid
- $CO_2 + H_20 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
- Body pH can be adjusted by changing rate and depth of breathing

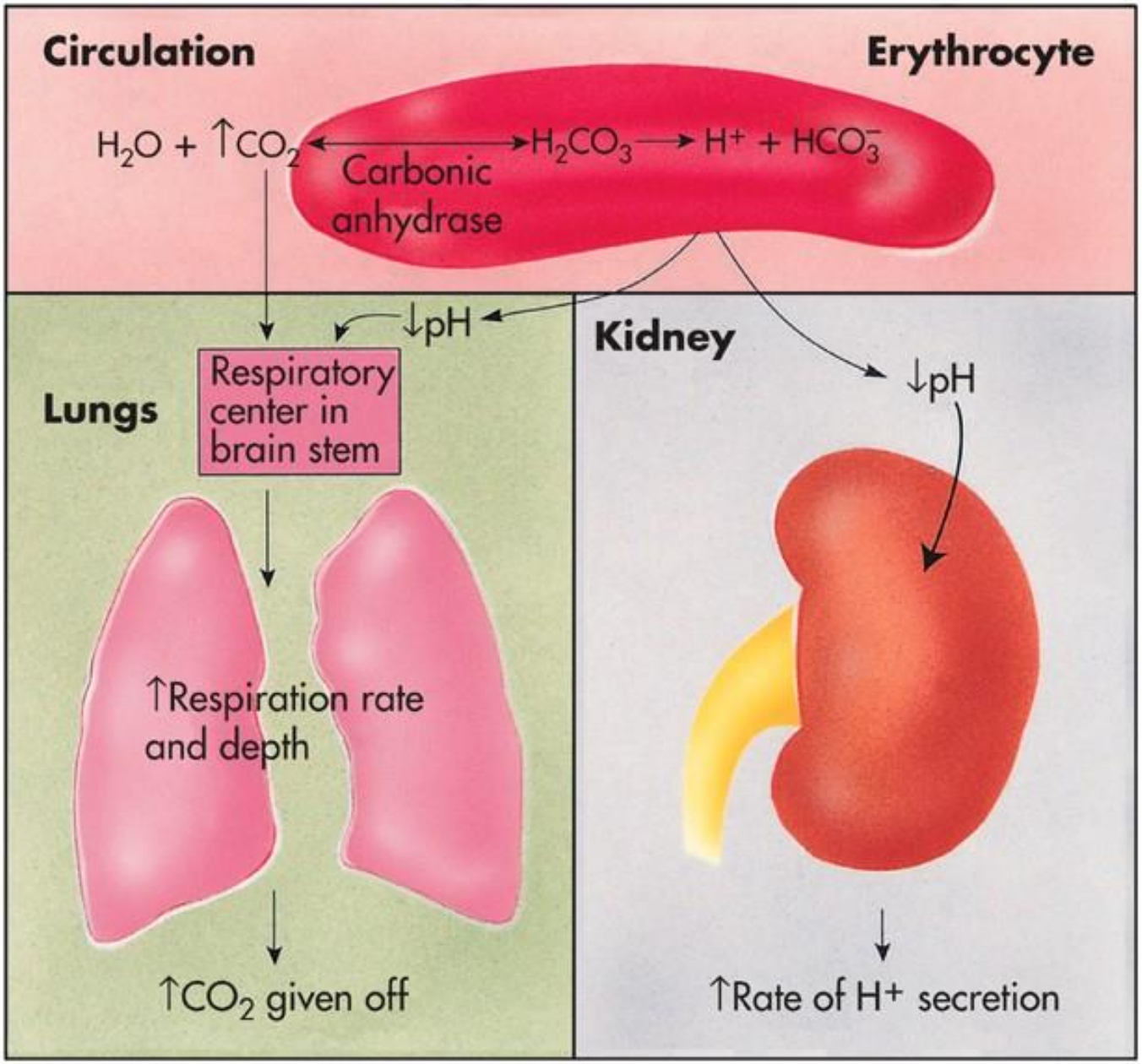
3. Kidney excretion

- Can eliminate large amounts of fixed acid
- Can also excrete base
- Can conserve and produce bicarbonate ions
- Most effective regulator of pH
- If kidneys fail, pH balance fails

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 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

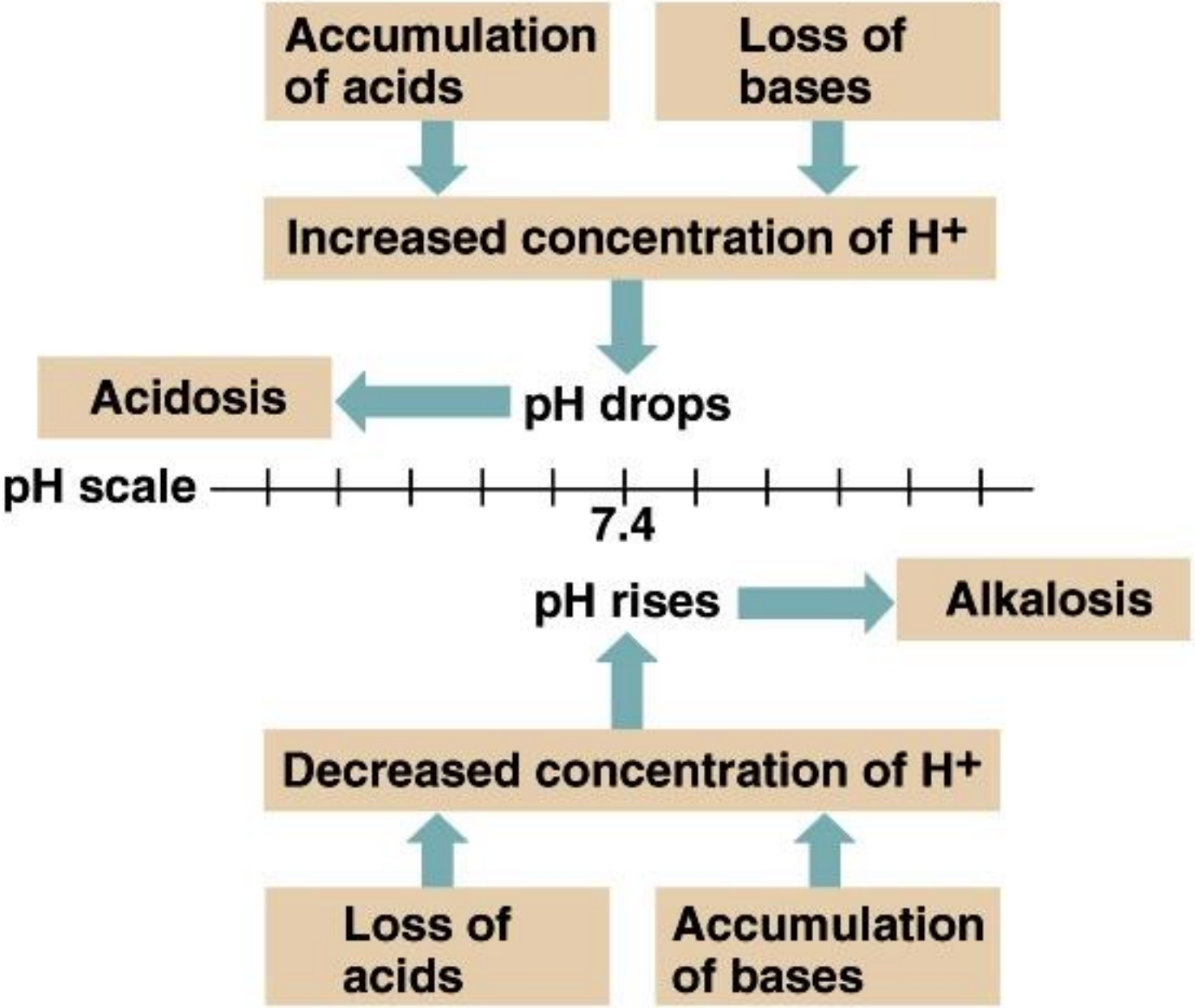
- If underlying problem is metabolic, hyperventilation or hypoventilation can help : **respiratory compensation**.
- If problem is respiratory, renal mechanisms can bring about **metabolic compensation.**

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
- Dizziness
- It can cause :
  - Nervousness
  - muscle spasms or tetany
  - Convulsions
  - Loss of consciousness
  - Death



Respiratory Acidosis

- **Carbonic acid excess** caused by blood levels of CO_2 above 45 mm Hg.
- **Hypercapnia –** high levels of CO_2 in blood
- Chronic conditions:
  - Depression of respiratory center in brain that controls breathing rate – drugs or head trauma
  - Paralysis of respiratory or chest muscles
  - Emphysema

Respiratory Acidosis

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

Compensation for Respiratory Acidosis

- There is no respiratory compensation for respiratory acidosis.
- **Renal compensation**: Kidneys eliminate hydrogen ion in form of NH_4 and H_2PO_4 and increase absorption of bicarbonate ion.

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

Respiratory Alkalosis

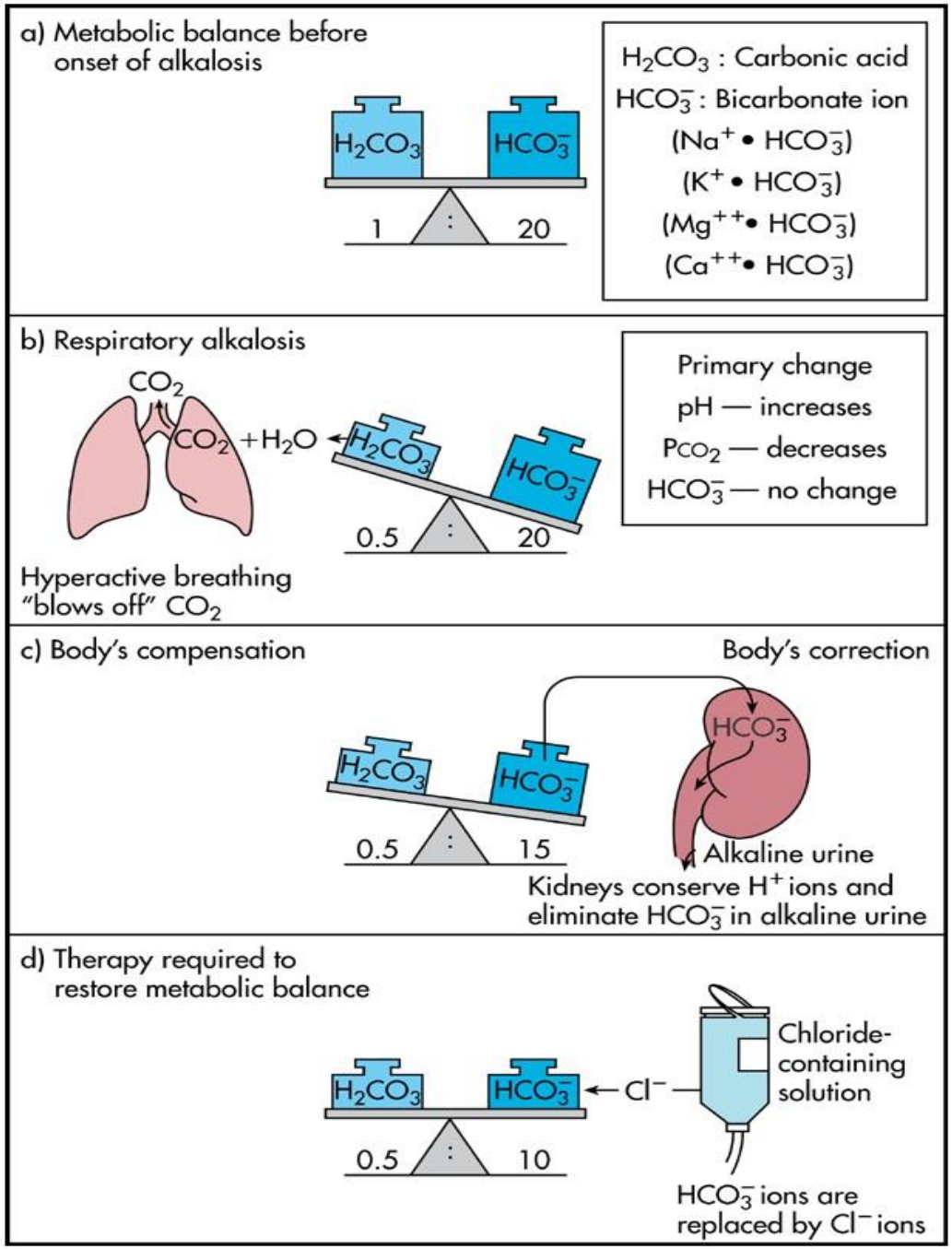
- Carbonic acid deficit
- pCO_2 less than 35 mm Hg (hypocapnea)
- Most common acid-base imbalance
- Primary cause is hyperventilation

Respiratory Alkalosis

- Conditions that stimulate respiratory center:
  - Oxygen deficiency at high altitudes
  - Pulmonary disease and Congestive heart failure – caused by hypoxia
  - Acute anxiety
  - Fever, anemia
  - Cirrhosis
  - hysteria ,tension ,pain, hypoxia , CNS injury

Compensation of Respiratory Alkalosis

- Kidneys conserve hydrogen ion
- Excrete bicarbonate ion



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Metabolic Acidosis

- **Bicarbonate deficit** - blood concentrations of bicarb drop below 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

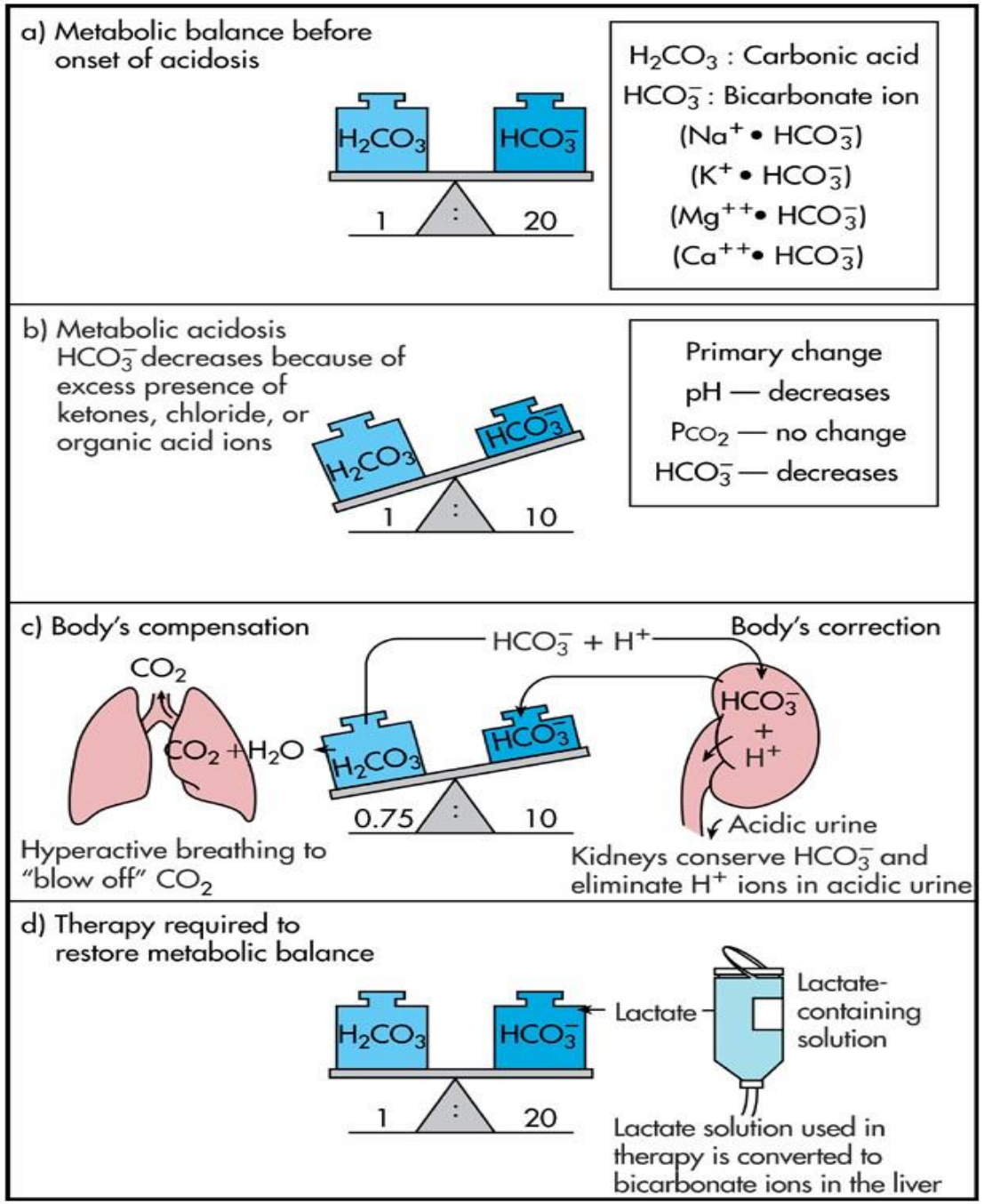
- Headache, lethargy
- Nausea, vomiting, diarrhea
- Coma
- Death

Compensation for Metabolic Acidosis

- Increased ventilation (repiratory comp)
- 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



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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
  - Severe dehydration

Compensation for Metabolic Alkalosis

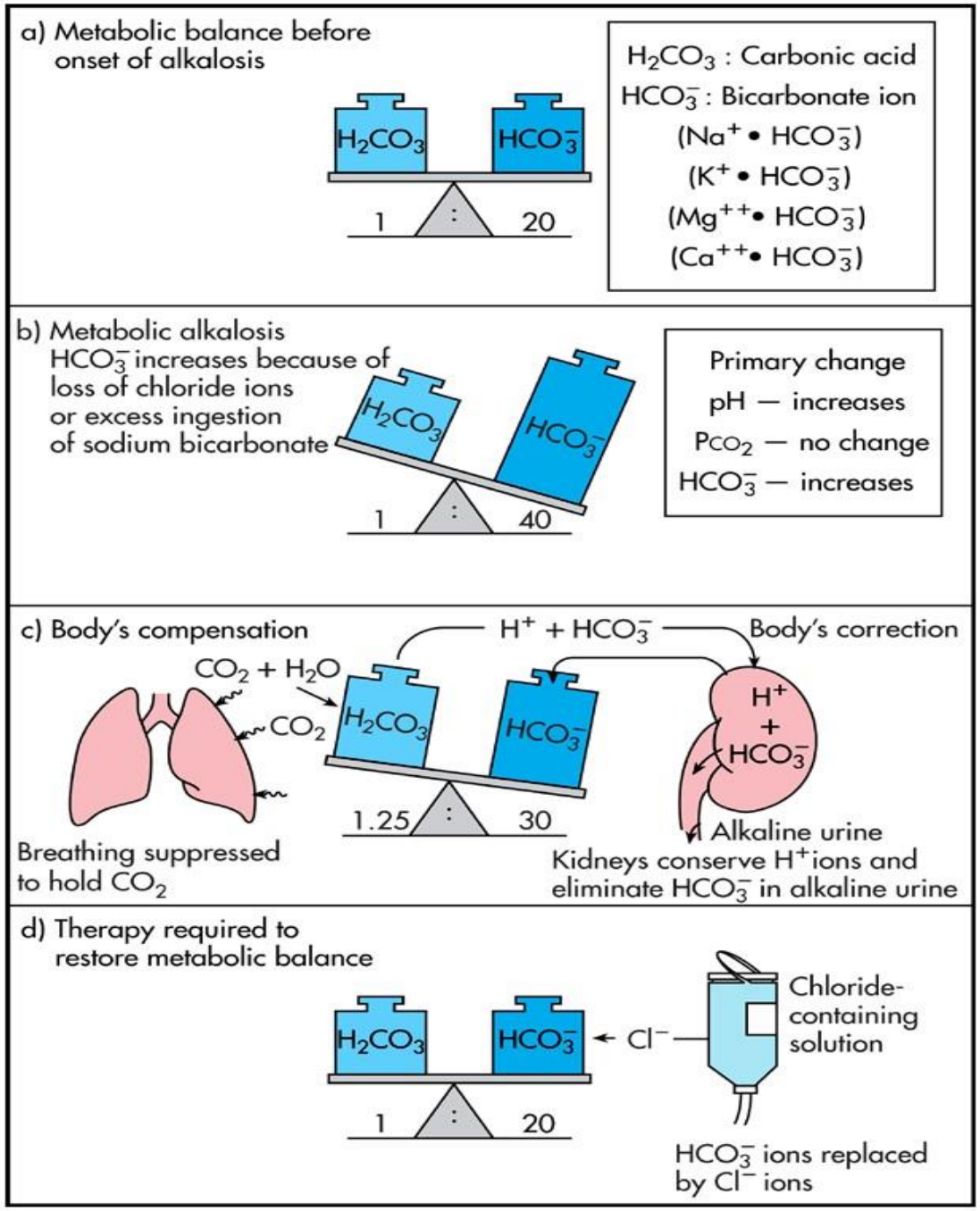
- Alkalosis most commonly occurs with renal dysfunction, so can’t count on kidneys
- Respiratory compensation

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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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 **and** could be the **cause** of the problem. If the cause is a change in pCO_2, the problem is respiratory. If the cause is HCO_3^- the problem is metabolic.

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THANKS