College of Medicine

Department of Medical Chemistry

Medical chemistry

Lecture No. ١

Acids , Bases and Salts in Medical Interests

First Stage

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What is an ACID?

- pH less than 7
- Neutralizes bases
- Forms H^+ ions in solution
- Corrosive-reacts with most metals to form hydrogen gas
- Good conductors of electricity
- Acids generate ions

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$

Weak & Strong Acids

- Weak Acids do not ionize completely: Acetic, Boric, Nitrous, Phosphoric, Sulfurous.
- Strong Acids ionize completely: Hydrochloric, Nitric; Sulfuric Hydriodic.

What is a BASE?

- pH greater than 7
- Feels slippery
- Dissolves fats and oils
- Usually forms OH^- ions in solution
- Neutralizes acids

$$NaOH(aq) \rightarrow Na^{+}(aq) + OH^{-}(aq)$$

Weak & Strong Bases

- Weak Bases do not ionize completely : ammonia, potassium carbonate, sodium carbonate.
- Strong Bases ionize completely : sodium hydroxide, sodium phosphate, barium hydroxide, calcium hydroxide

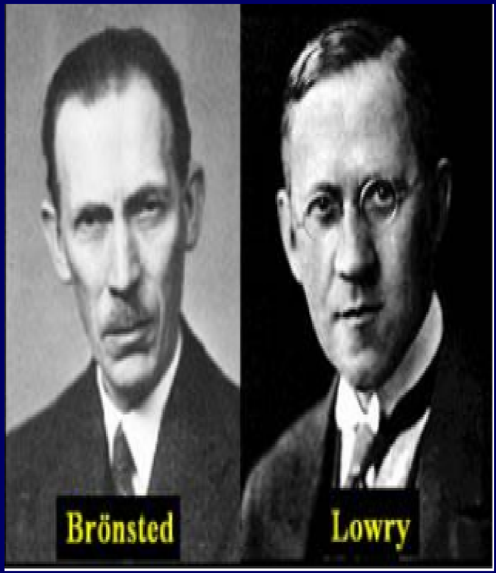
Definitions of acids and bases

Arrhenius

acid: generates $[H^+]$ in solution

base: generates $[OH^-]$ in solution

$$HCl + NaOH \longrightarrow NaCl + H_2O$$



Bronsted-Lowery:

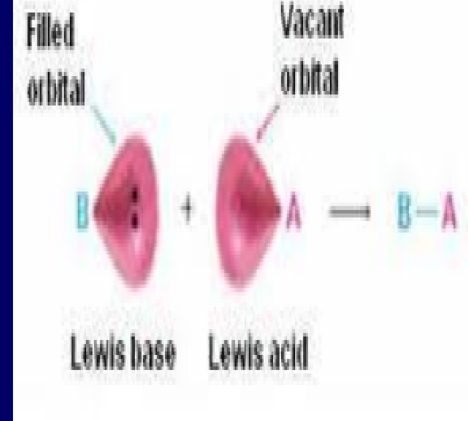
acid: anything that donates a $[H^+]$ (proton donor)

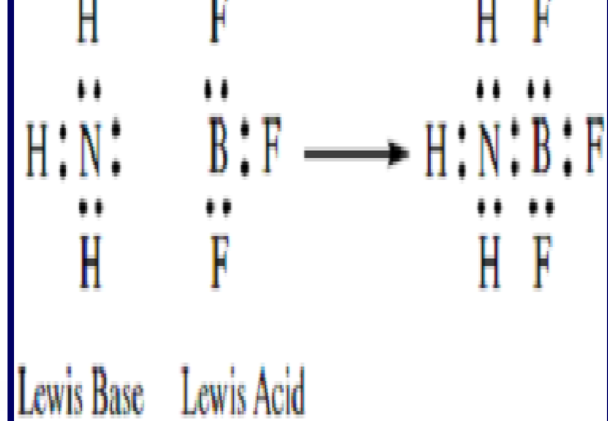
base: anything that accepts a $[H^+]$ (proton acceptor)

$$HNO_2 + H_2O \longrightarrow NO_2^- + H_3O^+$$

acid base conj. Base conj. acid

Lewis:





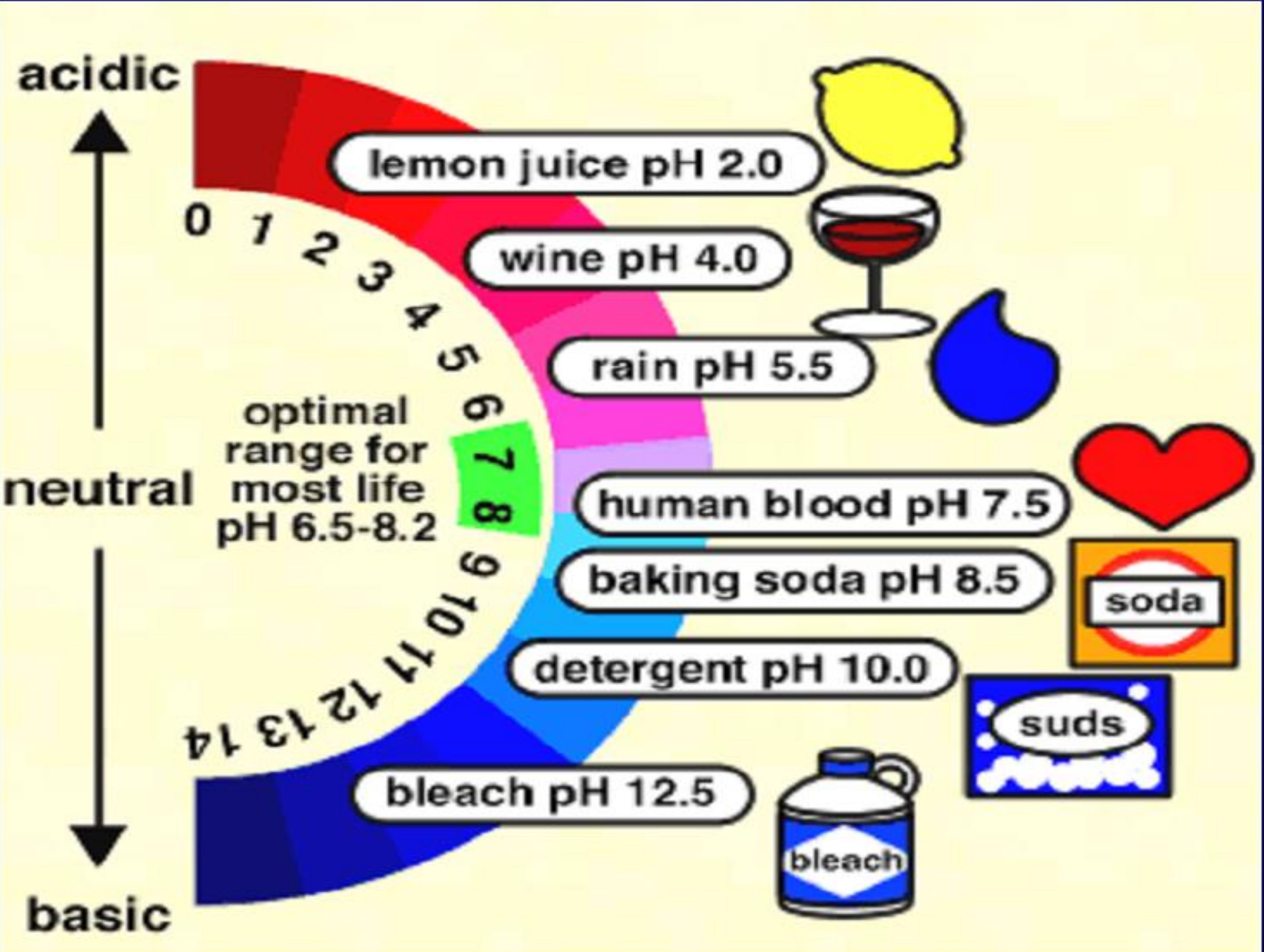
acid: accepts an electron pair

base: donates an electron pair

The advantage of this theory is that many reactions can be considered acid-base reactions because they do not have to occur in solution.

pH Scale

- The strength of an acid or base in a solution is measured on a scale called a pH scale or .
- The pH scale is a measure of the hydrogen ion concentration.


acidic
neutral
basic
lemon juice pH 2.0
wine pH 4.0
rain pH 5.5
human blood pH 7.5
baking soda pH 8.5
detergent pH 10.0
bleach pH 12.5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
optimal range for most life pH 6.5-8.2
soda
suds
bleach

What is a SALT?

- A salt is a neutral substance produced from the reaction of an acid and a base.
- Composed of the negative ion of an acid and the positive ion of a
- One of the products of a Neutralization Reaction

Examples: KCl, $MgSO_4$, Na_3PO_4

Source of acids and bases in the body

1. Inorganic acids produced during the breakdown of nutrients.

ingested nutrient with (sulfur and phosphorus) → breakdown → sulfuric acid; phosphoric acid

2. Organic acids resulting from intermediary metabolism.

- Fatty acids are produced during fat metabolism
- Lactic acid is produced by muscles during heavy exercise.

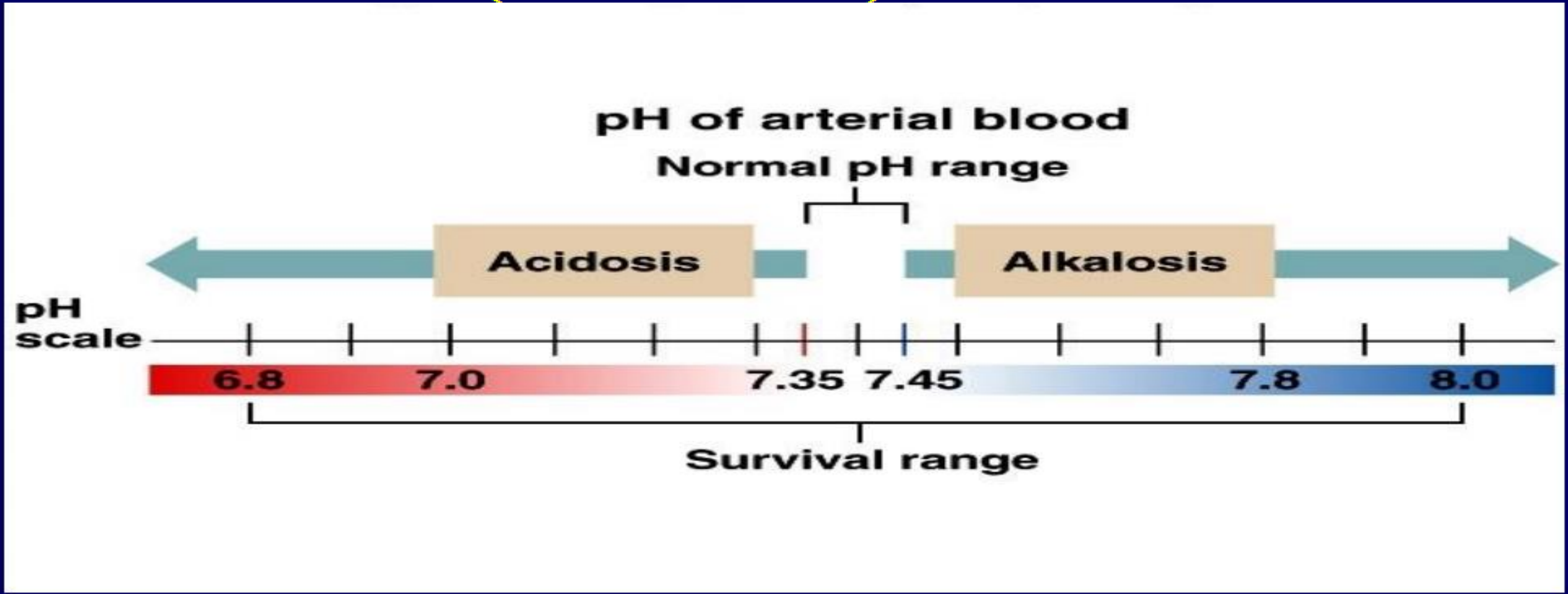
These acids partially dissociate to yield free H^+

3. Carbonic acid formation

Cellular oxidation → $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ (carbonic anhydrase enzyme)

The Body and pH

- Homeostasis of pH is tightly controlled
- Extracellular fluid = 7.4
- Blood = 7.35 – 7.45
- < 6.8 or > 8.0 death occurs
- **Acidosis** (acidemia) below 7.35
- **Alkalosis** (alkalemia) above 7.45



3. Changes in [H^+] influence K^+ levels in the body.

- **If more H^+ than normal is eliminated by the kidneys the body fluids become acidotic, less K^+ than usual can be excreted.**
- **The resultant K^+ retention can affect cardiac function.**

Acid-base balance

- Hydrogen-ion generation therefore normally goes on continuously as a result of on going metabolic activities.

- But, in certain states, additional acids may be produced that further contribute to the total body pool of H^+.

For example

- In diabetes mellitus, large quantities of keto acids may be produced as a result of abnormal fat metabolism.

Effects of fluctuations in hydrogen-ion concentration on body chemistry

The prominent consequences of fluctuations in $[H^+]$ include the following:

1. Changes in excitability of nerve and muscle cells.

- The major clinical effect of increased $[H^+]$ (acidosis) is depression of the central nervous system.
- The major clinical effect of decreased $[H^+]$ (alkalosis) is over excitability of the nervous system

2. Hydrogen-ion concentration exerts a marked influence on enzyme activity.

- Since enzymes are proteins, a shift in the body acid-base balance disturbs the normal pattern of metabolic activity catalyzed by these enzymes
- Some cellular chemical reactions are accelerated; others are depressed.

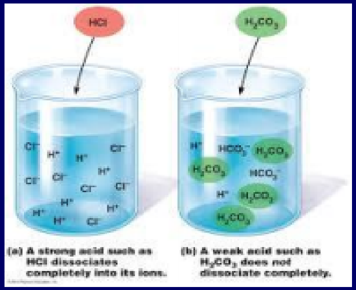
- o Some types of acid-producing medications may also add to the total load of H^+ that must be handled by the body.

- Thus, input of H^+ is unceasing, highly variable, and essentially unregulated.

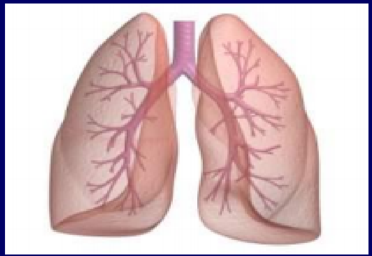
How can keep the balance of the acid in the body?

Three lines of defense against changes in $[H^+]$ operate to maintain the $[H^+]$ of body fluids at a nearly constant level despite unregulated input:

(1) The chemical buffer systems.



(2) The respiratory mechanism of pH control.



(3) The renal mechanism of pH control.

1.The chemical buffer systems of the body

There are three major buffer system the pH of the body

a. Carbonate buffer

$$H_2CO_3 + H_2O \leftrightarrow H_3O^+ + HCO_3^-$$

Excess acid (H_3O^+) in the body is neutralized by HCO_3^-

$$H_2CO_3 + H_2O \leftarrow H_3O^+ + HCO_3^-$$

Equilibrium shifts left

Excess base (OH^-) reacts with the carbonic acid (H_2CO_3)

$$H_2CO_3 + OH^- \rightarrow H_2O + HCO_3^-$$

Equilibrium shifts right

pH of the blood buffer

The concentrations of H_2CO_3 and HCO_3^- in the blood are 0.0024M and 0.024M respectively

H_2CO_3/ HCO_3^- = 1/10 is needed to maintain the normal blood pH (7.35 – 7.45)

$$K_a = \frac{[H_3O]^+ [HCO_3^-]}{[H_2CO_3]}$$

$$[H_3O]^+ = K_a^+ \frac{[H_2CO_3]}{[HCO_3^-]}$$

$$= 4.3 \times 10^{-7} \times \frac{0.0024}{0.024} = 4.3 \times 10^{-7} \times 0.10 = 4.3 \times 10^{-8}$$

$$pH = -\log(4.3\times10^{-8}) = 7.37$$

b. phosphate buffer

The phosphate buffer system ($HPO_4^{2-}/H_2PO_4^{-}$) plays a role in plasma and erythrocytes.

$$H_2PO_4^{-} + H_2O \leftrightarrow H_3O^{+} + HPO_4^{2-}$$

Any acid reacts with monohydrogen phosphate to form dihydrogen phosphate

$$H_2PO_4^{-} + H_2O \leftarrow HPO_4^{2-} + H_3O^{+}$$

The base is neutralized by dihydrogen phosphate

$$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_3O^+$$

c. Proteins buffer

Proteins contain $-\ COO^-$ groups, which, like acetate ions (CH_3COO^-), can act as proton acceptors.

Proteins also contain $-\ NH_3^+$ groups, which, like ammonium ions (NH_4^+), can donate protons.

If acid comes into blood, hydronium ions can be neutralized by the $-\ COO^-$ groups

$$-\ COO^- + H_3O^+ \rightarrow -\ COOH + H_2O$$

If base is added, it can be neutralized by the $-\ NH_3^+$ groups

$$-NH_3^+ + OH^- \rightarrow -NH_2 + H_2O$$

2. The respiratory mechanism of pH control.

- Amount of blood carbon dioxide directly relates to amount of carbonic acid and therefore to concentration of H^+
- With increased respirations, less carbon dioxide remains in blood, hence less carbonic acid and fewer H^+
- With decreased respirations, more carbon dioxide remains in blood, hence more carbonic acid and more H^+.

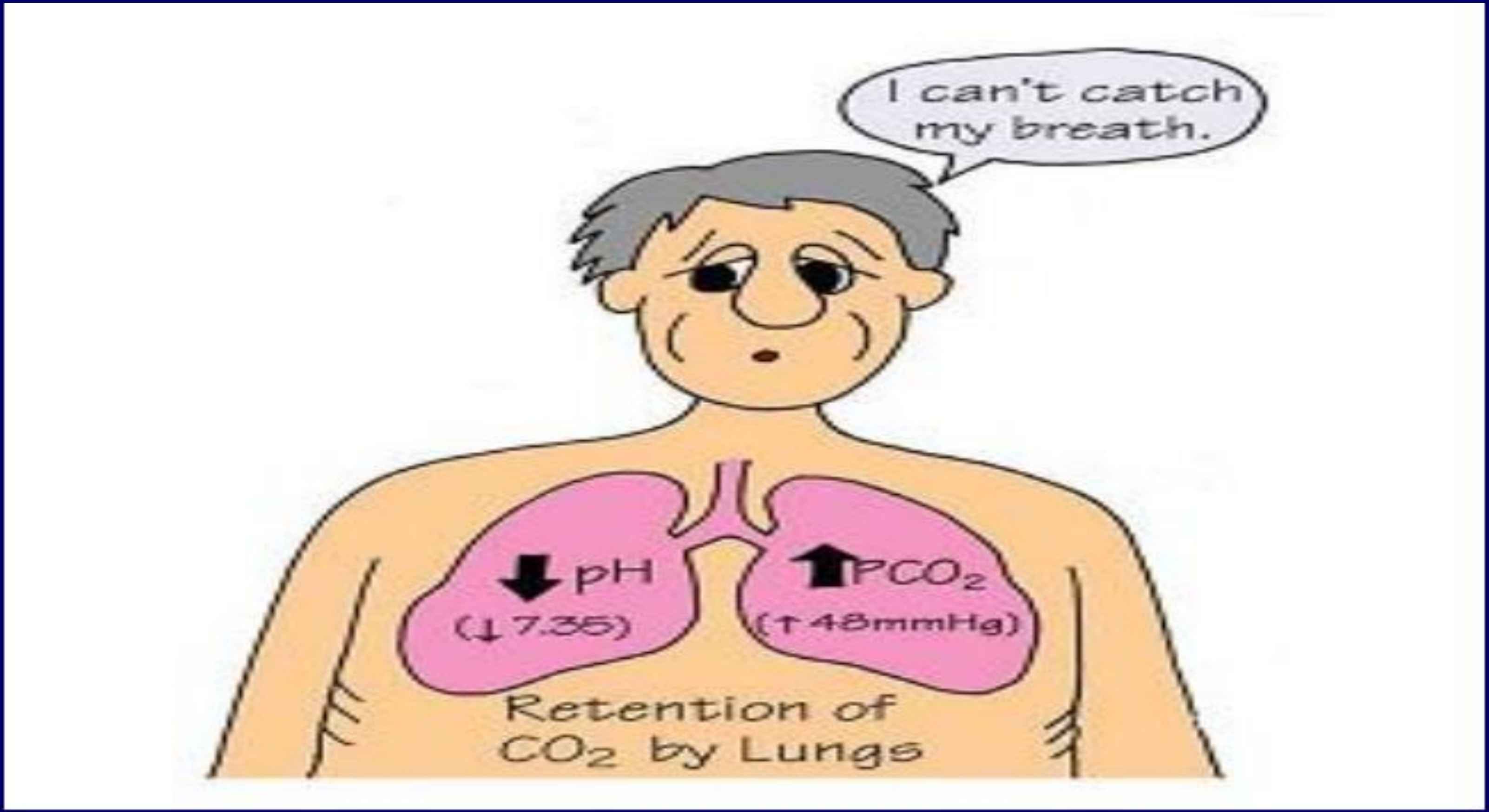
Carbon dioxide levels and pH affect respiratory centers

Hypoventilation increases blood carbon dioxide levels
Hyperventilation decreases blood carbon dioxide levels

Respiratory Acidosis

- **Carbonic acid excess** caused by blood levels of CO_2 above 45 mm Hg.

- **Hypercapnia** – high levels of CO_2 in blood



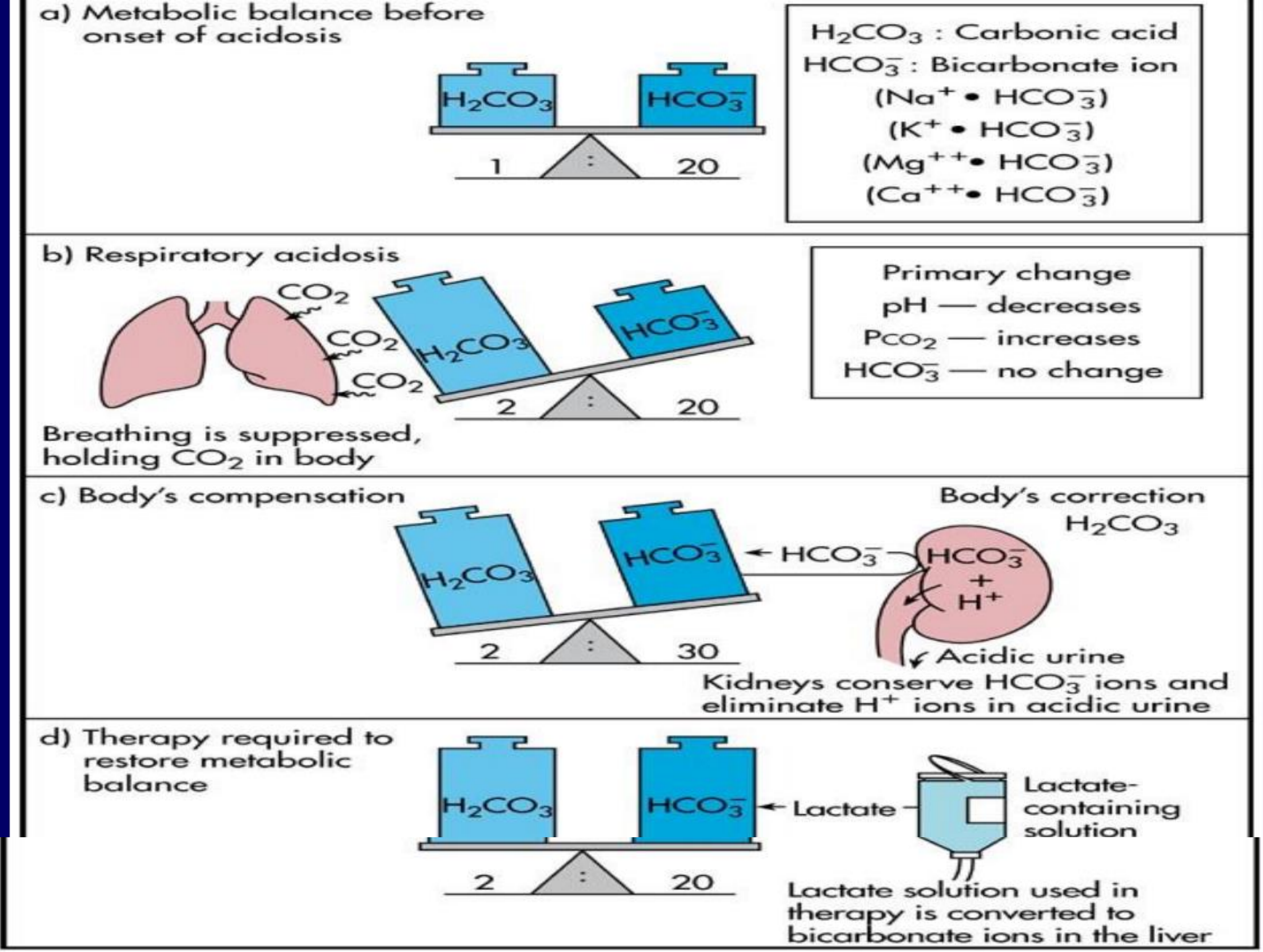
Compensation for Respiratory Acidosis

- The body response to acid-base imbalance is called compensation
- Kidneys eliminate hydrogen ion and retain bicarbonate ion

Treatment of Respiratory Acidosis

Restore ventilation

IV lactate solution



a) Metabolic balance before onset of acidosis
H_2CO_3
HCO_3^-
1 : 20
H_2CO_3 : Carbonic acid
HCO_3^- : Bicarbonate ion
($Na^+ \bullet HCO_3^-$)
($K^+ \bullet HCO_3^-$)
($Mg^{++} \bullet HCO_3^-$)
($Ca^{++} \bullet HCO_3^-$)
b) Respiratory acidosis
CO_2
CO_2
CO_2
H_2CO_3
HCO_3^-
2 : 20
Breathing is suppressed, holding CO_2 in body
Primary change
pH — decreases
P_{CO_2} — increases
HCO_3^- — no change
c) Body's compensation
H_2CO_3
HCO_3^-
2 : 30
Body's correction
H_2CO_3
HCO_3^-
HCO_3^- + H^+
Acidic urine
Kidneys conserve HCO_3^- ions and eliminate H^+ ions in acidic urine
d) Therapy required to restore metabolic balance
H_2CO_3
HCO_3^-
Lactate
Lactate-containing solution
2 : 20
Lactate solution used in therapy is converted to bicarbonate ions in the liver

Respiratory Alkalosis

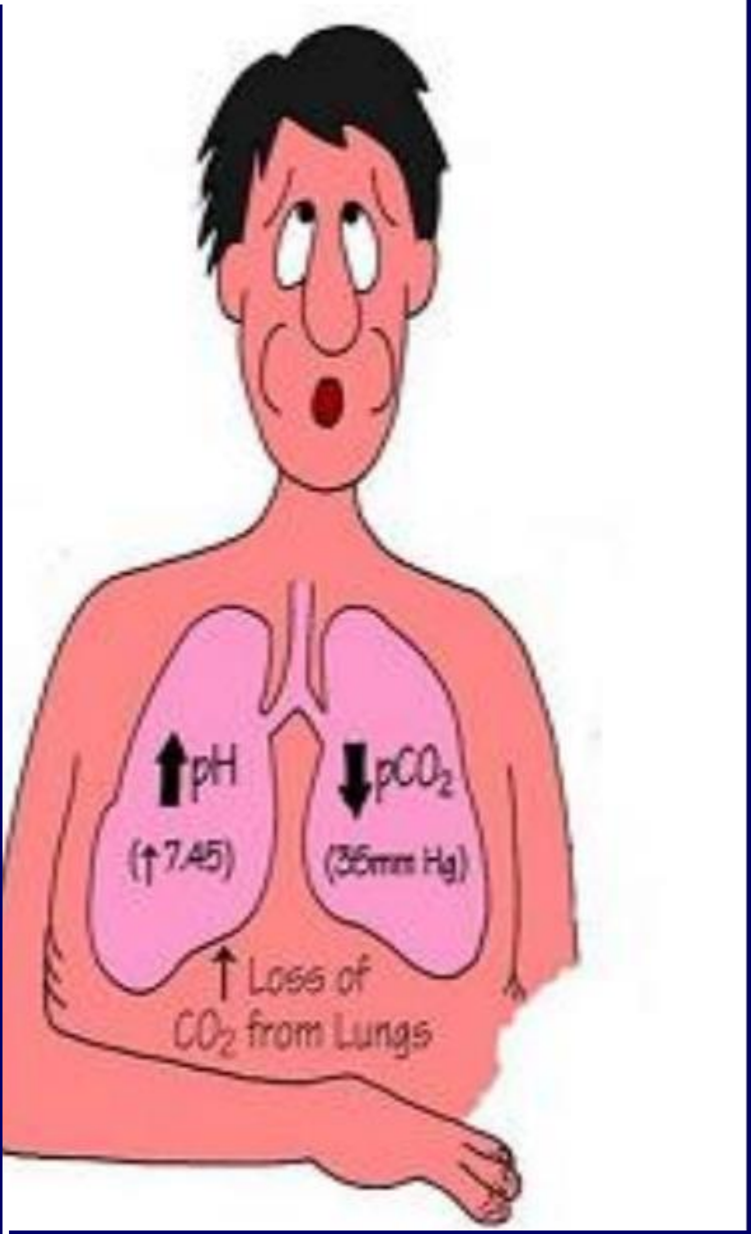
- Carbonic acid deficit
- pCO_2 less than 35 mm Hg (hypocapnea)
- Most common acid-base imbalance
- Primary cause is hyperventilation

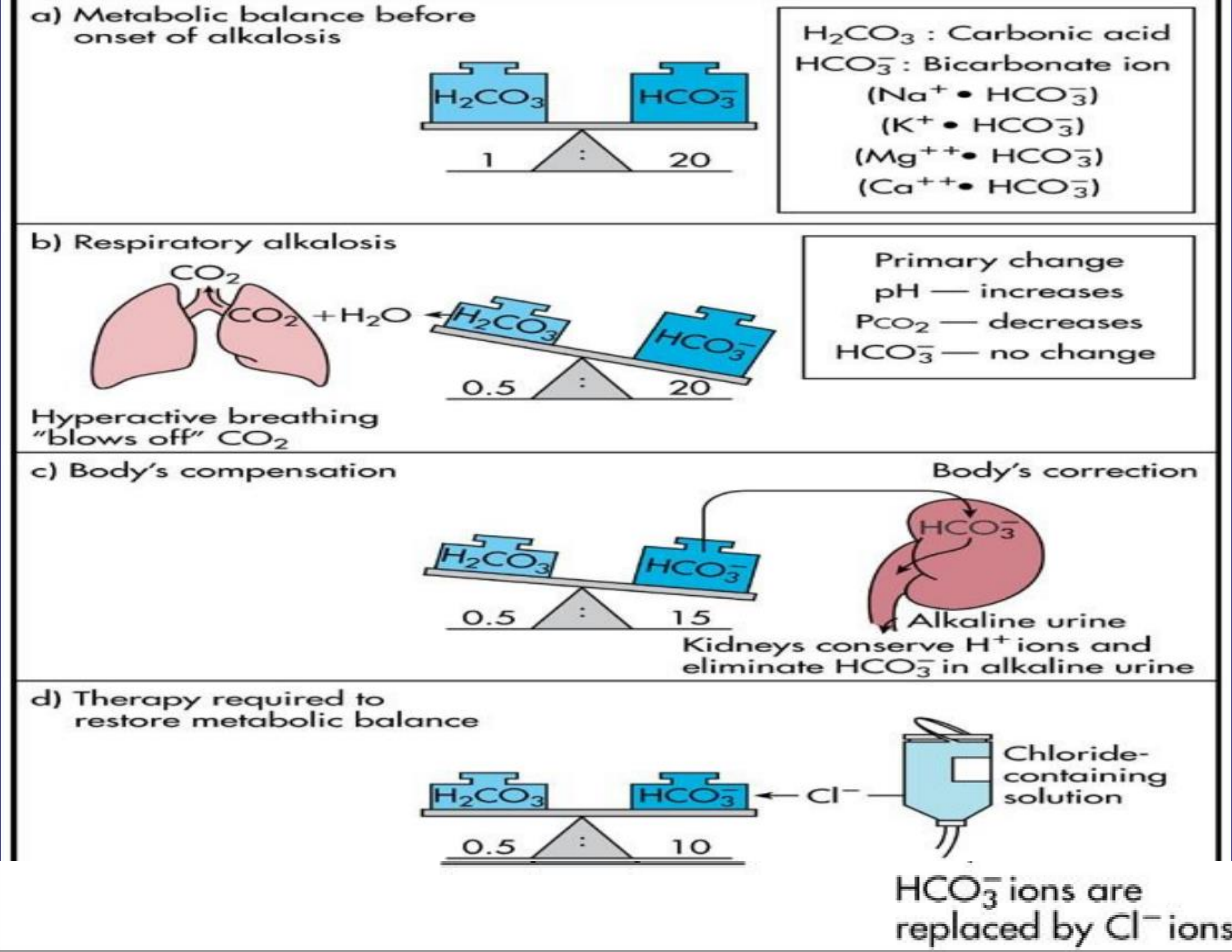
Compensation of Respiratory Alkalosis

- Kidneys conserve hydrogen ion
- Excrete bicarbonate ion

Treatment of Respiratory Alkalosis

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




a) Metabolic balance before onset of alkalosis
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($Na^+ \bullet HCO_3^-$)
($K^+ \bullet HCO_3^-$)
($Mg^{++} \bullet HCO_3^-$)
($Ca^{++} \bullet HCO_3^-$)
b) Respiratory alkalosis
CO_2
$CO_2 + H_2O$
H_2CO_3
HCO_3^-
0.5
20
Hyperactive breathing "blows off" CO_2
Primary change
pH — increases
P_{CO_2} — decreases
HCO_3^- — no change
c) Body's compensation
Body's correction
H_2CO_3
HCO_3^-
0.5
15
HCO_3^-
Alkaline urine
Kidneys conserve H^+ ions and eliminate HCO_3^- in alkaline urine
d) Therapy required to restore metabolic balance
H_2CO_3
HCO_3^-
Cl^-
Chloride-containing solution
0.5
10
HCO_3^- ions are replaced by Cl^- ions

3.The renal mechanism of pH control.

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

Metabolic Acidosis

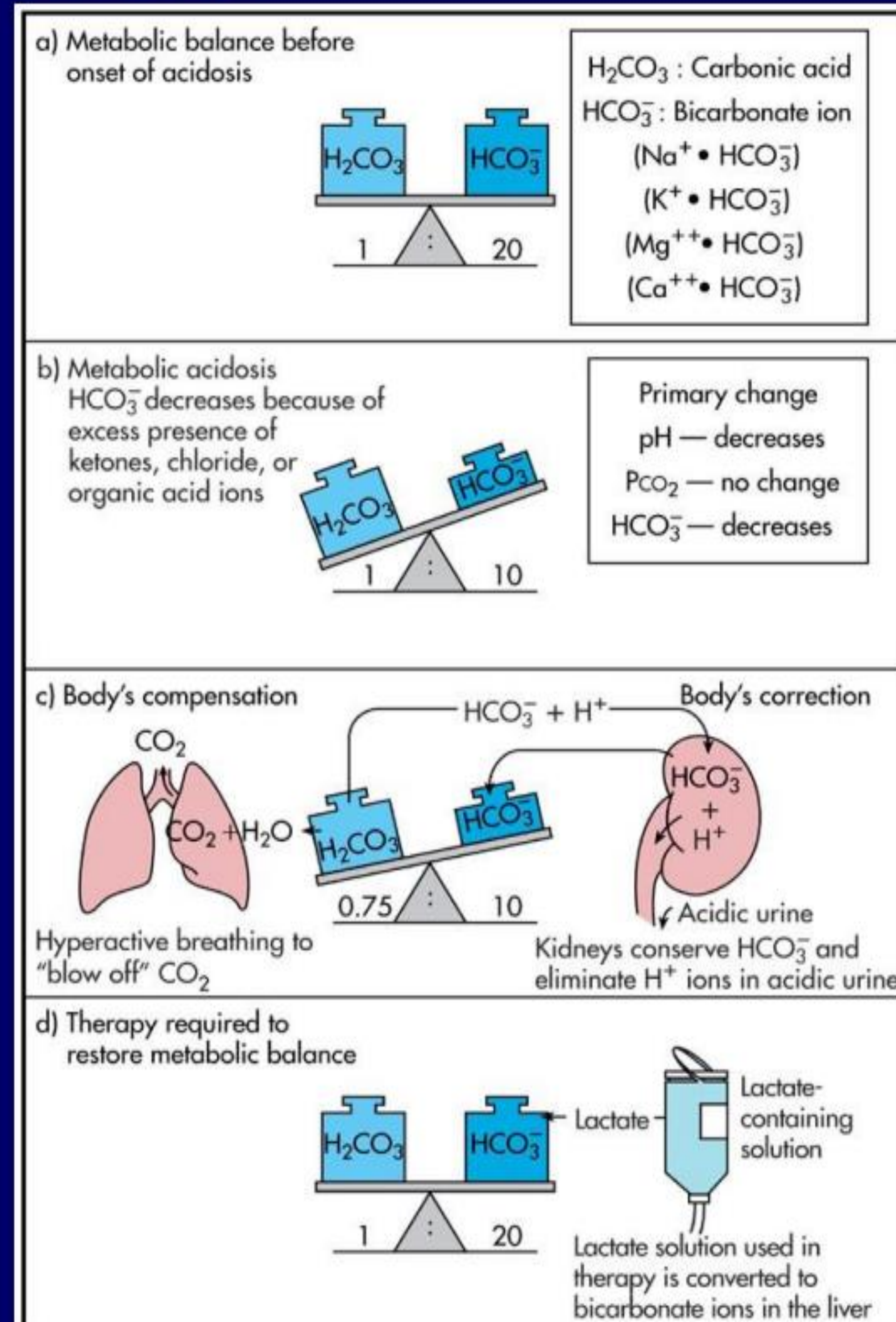
- **Bicarbonate deficit** - blood concentrations of bicarbonate drop below 22mEq/L
- **Causes:**
  - Loss of bicarbonate through diarrhea or renal dysfunction
  - Accumulation of acids (lactic acid or ketones)
  - Failure of kidneys to excrete H+

Symptoms of Metabolic Acidosis

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

Compensation for Metabolic Acidosis

- Increased ventilation
- 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

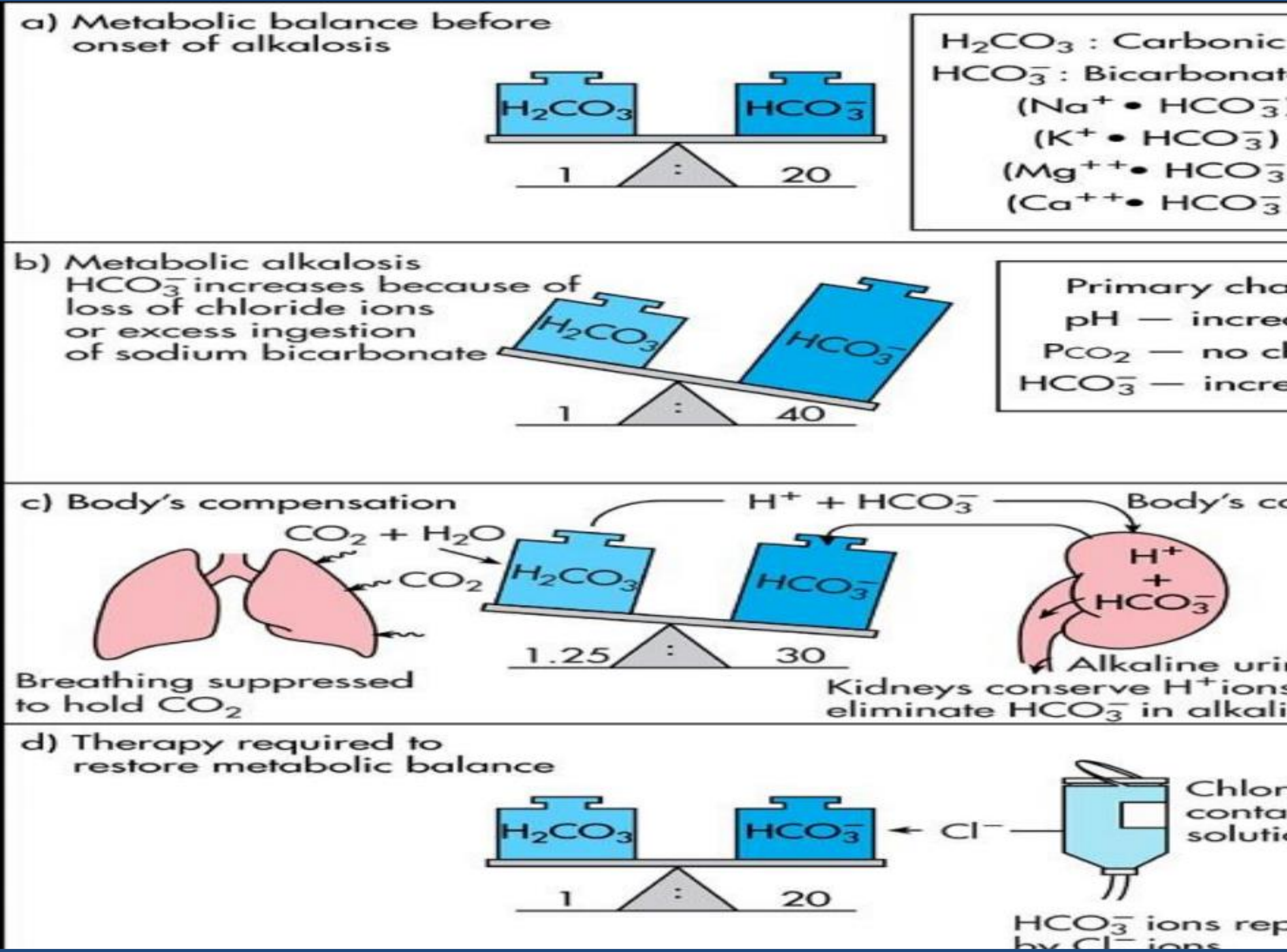
- Bicarbonate excess - concentration in blood is greater than 26 mEq/L
- **Causes:**
  - Excess vomiting = loss of stomach acid
  - Excessive use of alkaline drugs
  - Certain diuretics
  - Endocrine disorders
  - Heavy ingestion of antacids
  - Severe dehydration

Compensation for Metabolic Alkalosis

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

Treatment of Metabolic Alkalosis

- Electrolytes to replace those lost
- IV chloride containing solution



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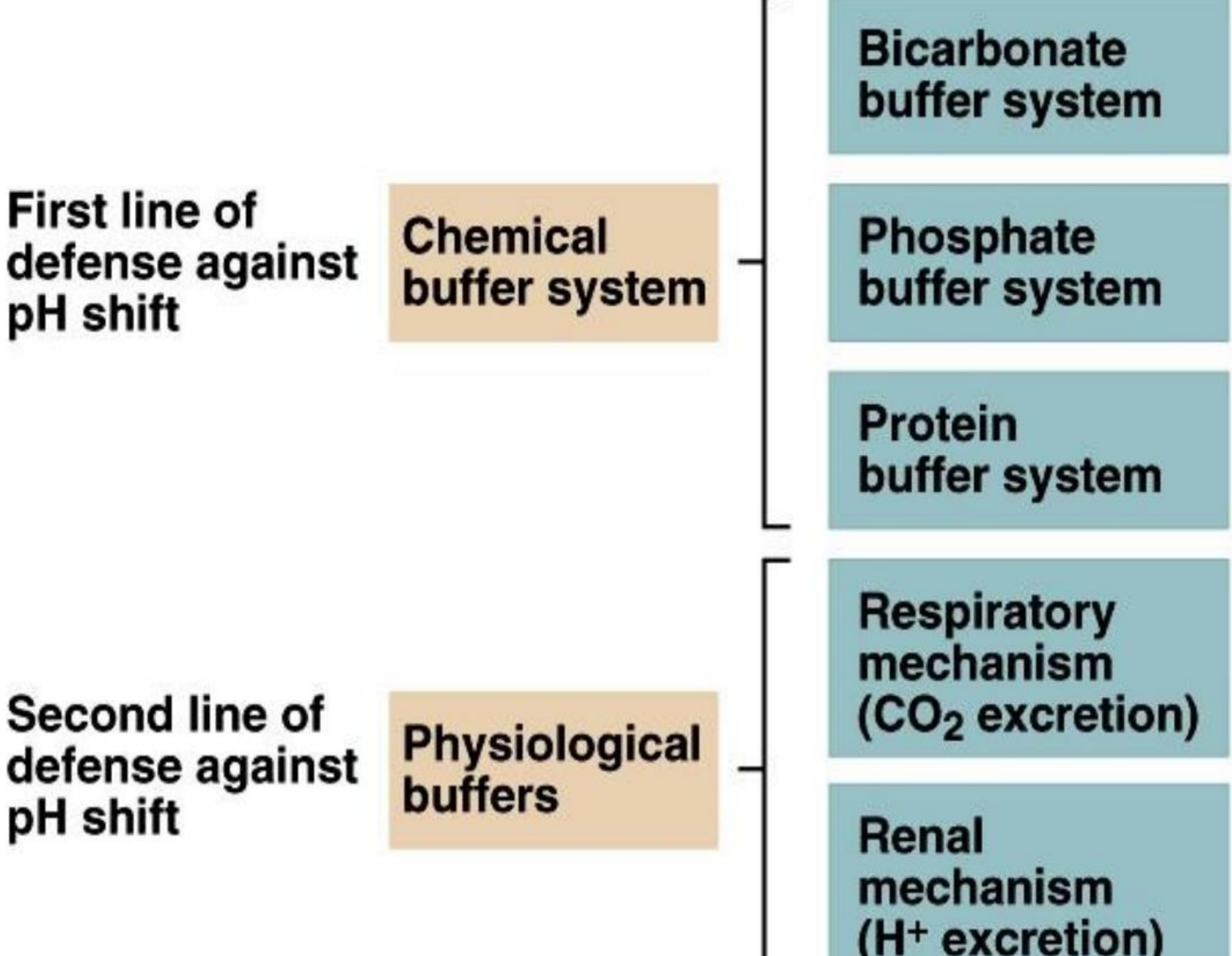
1 : 20
H_2CO_3 : Carbonic
HCO_3^- : Bicarbonat
($Na^+ \bullet HCO_3^-$
($K^+ \bullet HCO_3^-$)
($Mg^{++} \bullet HCO_3^-$
($Ca^{++} \bullet HCO_3^-$
b) Metabolic alkalosis
HCO_3^- increases because of loss of chloride ions or excess ingestion of sodium bicarbonate
H_2CO_3
HCO_3^-
1 : 40
Primary cha
pH — incre
P_{CO_2} — no c
HCO_3^- — incre
c) Body's compensation
$CO_2 + H_2O$
CO_2
$H^+ + HCO_3^-$
Body's co
H_2CO_3
HCO_3^-
1.25 : 30
H^+ + HCO_3^-
Alkaline uri
Breathing suppressed to hold CO_2
Kidneys conserve H^+ ions
eliminate HCO_3^- in alkali
d) Therapy required to restore metabolic balance
H_2CO_3
HCO_3^-
Cl^-
1 : 20
Chlor
conta
soluti
HCO_3^- ions rep


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)

Rates of correction

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

Diagnosis of Acid-Base Imbalances

1. Note whether the pH is low (acidosis) or high (alkalosis)

2. Decide which value, is outside the normal range and could be the cause of the problem pCO_2 or HCO_3^- .

If the cause is a change in pCO_2, the problem is respiratory.

If the cause is HCO_3^- the problem is metabolic.

3. Look at the value that doesn't correspond to the observe
pH change whether its inside or outside the normal range.

If it is inside the normal range, there is no compensation occurring.

If it is outside the normal range, the body is partially compensating for the problem.

Example:- A patient is in intensive care because he suffered a severe myocardial infarction 3 day
ago. The lab reports the following values from an arterial blood sample:

pH 7.3

HCO_3^- = 20 mEq / L (22 - 26)

pCO2 = 32 mm Hg (35 - 45)

Diagnosis : Metabolic acidosis
With compensation


Thank you for your attention