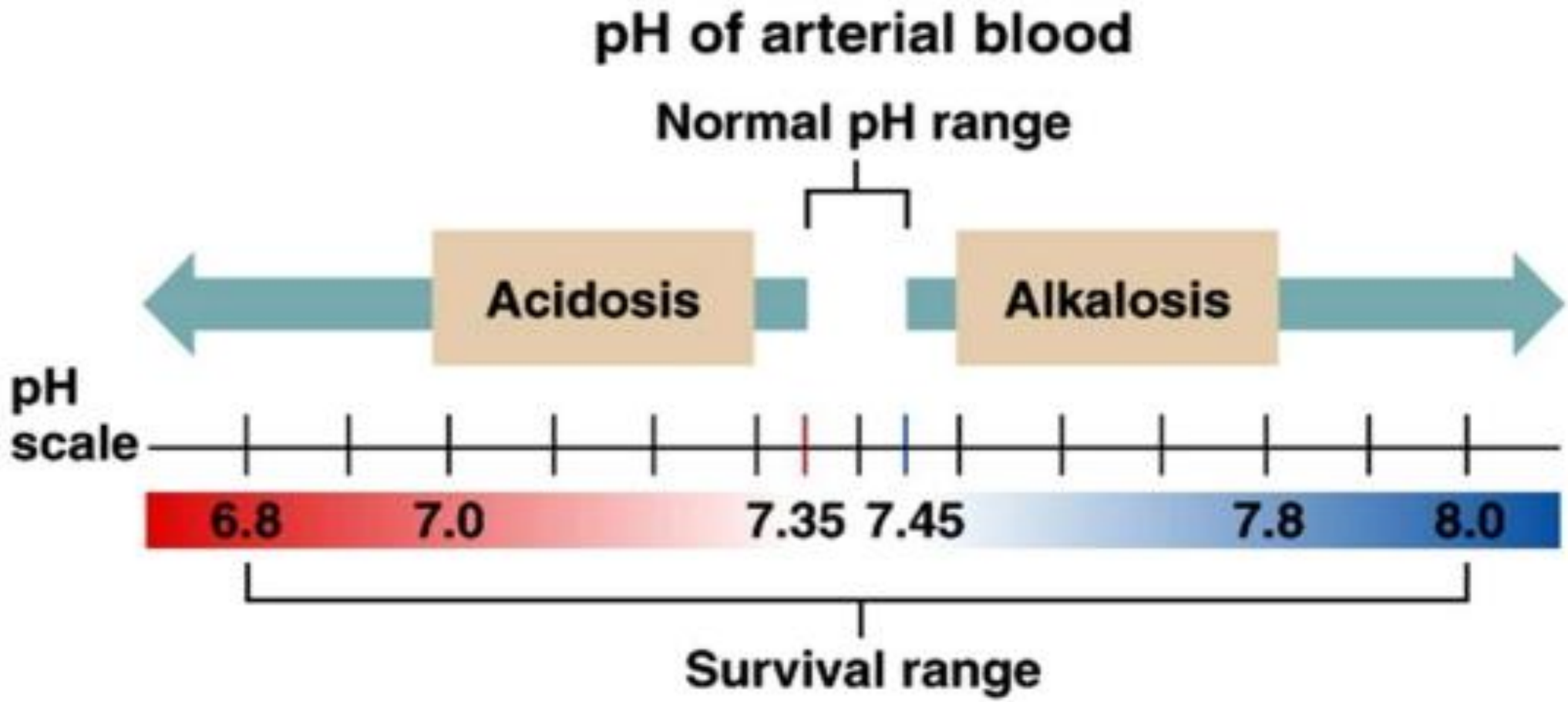
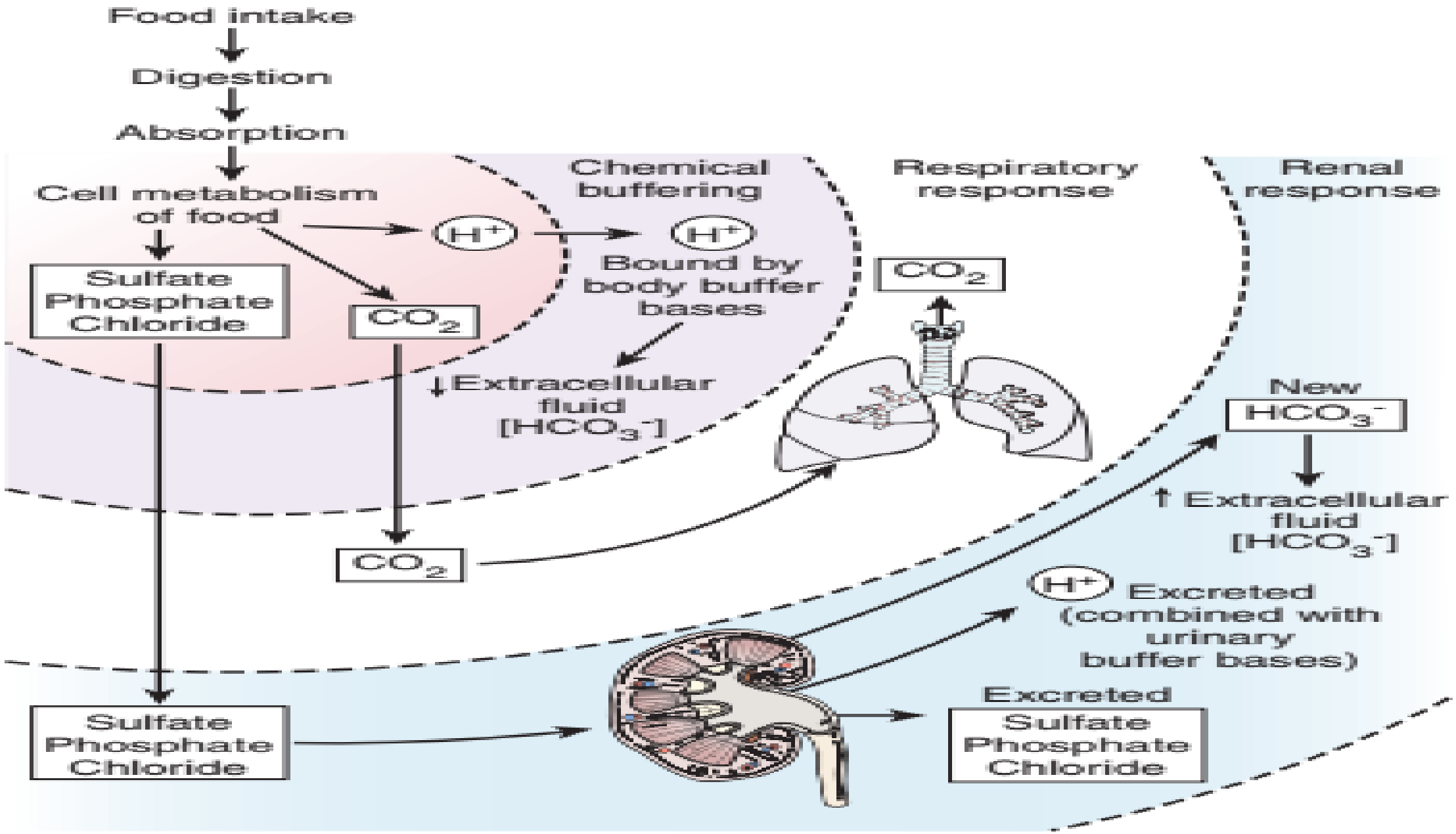
Pathology of acid-alkaline balance and laboratory diagnostics




Food intake
Digestion
Absorption
Cell metabolism of food
Sulfate
Phosphate
Chloride
H^+
CO_2
Chemical buffering
H^+
Bound by body buffer bases
↓Extracellular fluid [HCO_3^-]
CO_2
Respiratory response
CO_2
Renal response
New HCO_3^-
↑ Extracellular fluid [HCO_3^-]
H^+ Excreted (combined with urinary buffer bases)
Excreted
Sulfate
Phosphate
Chloride
Sulfate
Phosphate
Chloride

Respiratory acidosis

Metabolic acidosis

Respiratory alkalosis

Metabolic alkalosis

Respiratory acidosis→

pCO2 ↑, pH ↓→ Compensation-HCO3 ↑

Respiratory alkalosis →

pCO2↓, pH ↑→ Compensation-HCO3↓

Metabolic acidosis→

pH↓, HCO3 ↓→Compensation -pCO2 ↓

Metabolic alkalosis →

pH ↑, HCO3↑→ Compensation-pCO2 ↑

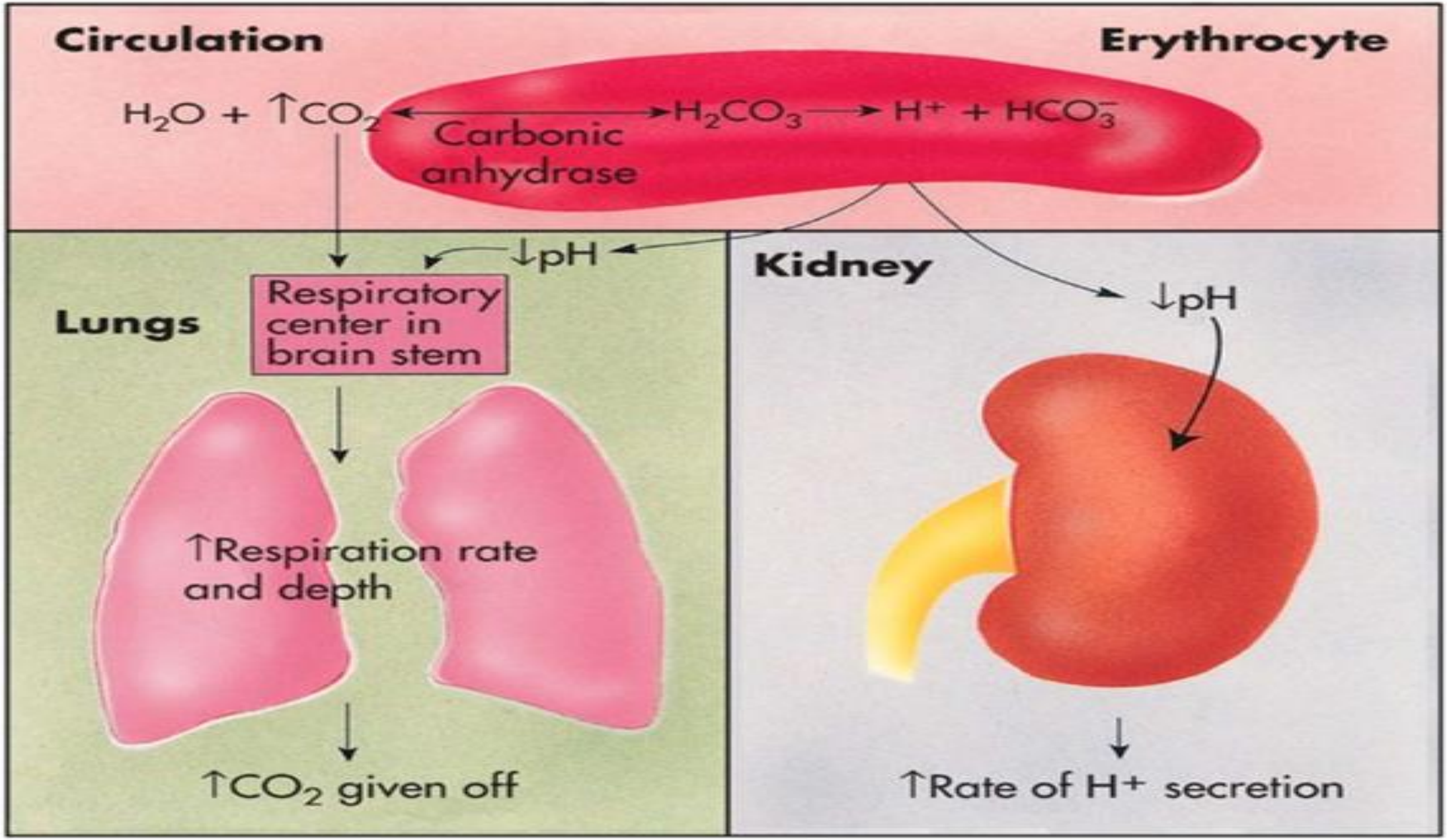
BUFFER SYSTEMS

***Bicarbonate system* -**keeps the pH of the extracellular fluid stable

***Phosphate* system -**determines the pH of renal tubule fluid, intracellular fluid

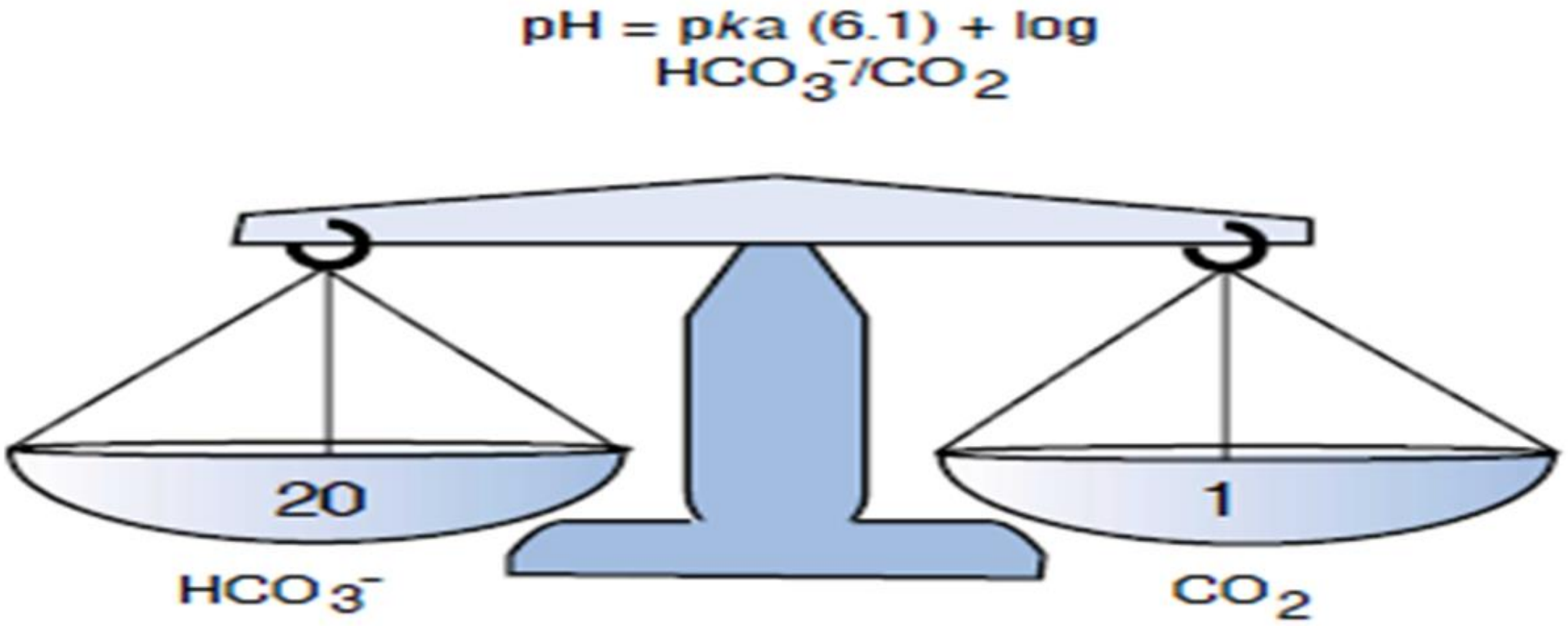
Protein system- *determines intracellular pH*

Hemoglobin system - *transports oxygen and carbon dioxide*



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

1) *Normal blood pH is 7.35-7.45,*
2) *pCO2 of blood -35-45 mm. Hg.*
3) *Standard Bicarbonate (SB) is normally 22-26 mmol/l,*
4) *BB (buffer basis)-40-48 mmol/l,*
5) *BE – («Base Excess») –2.5µmol/l*



Organs involved in the regulation of acid-alkaline balance

Lungs, kidneys, liver, gastrointestinal tract
Stomach→HCI secretion,
Pancreas and intestine → secretion of bicarbonates
Kidney→acidogenesis and ammonogenesis processes, secretion of phosphates

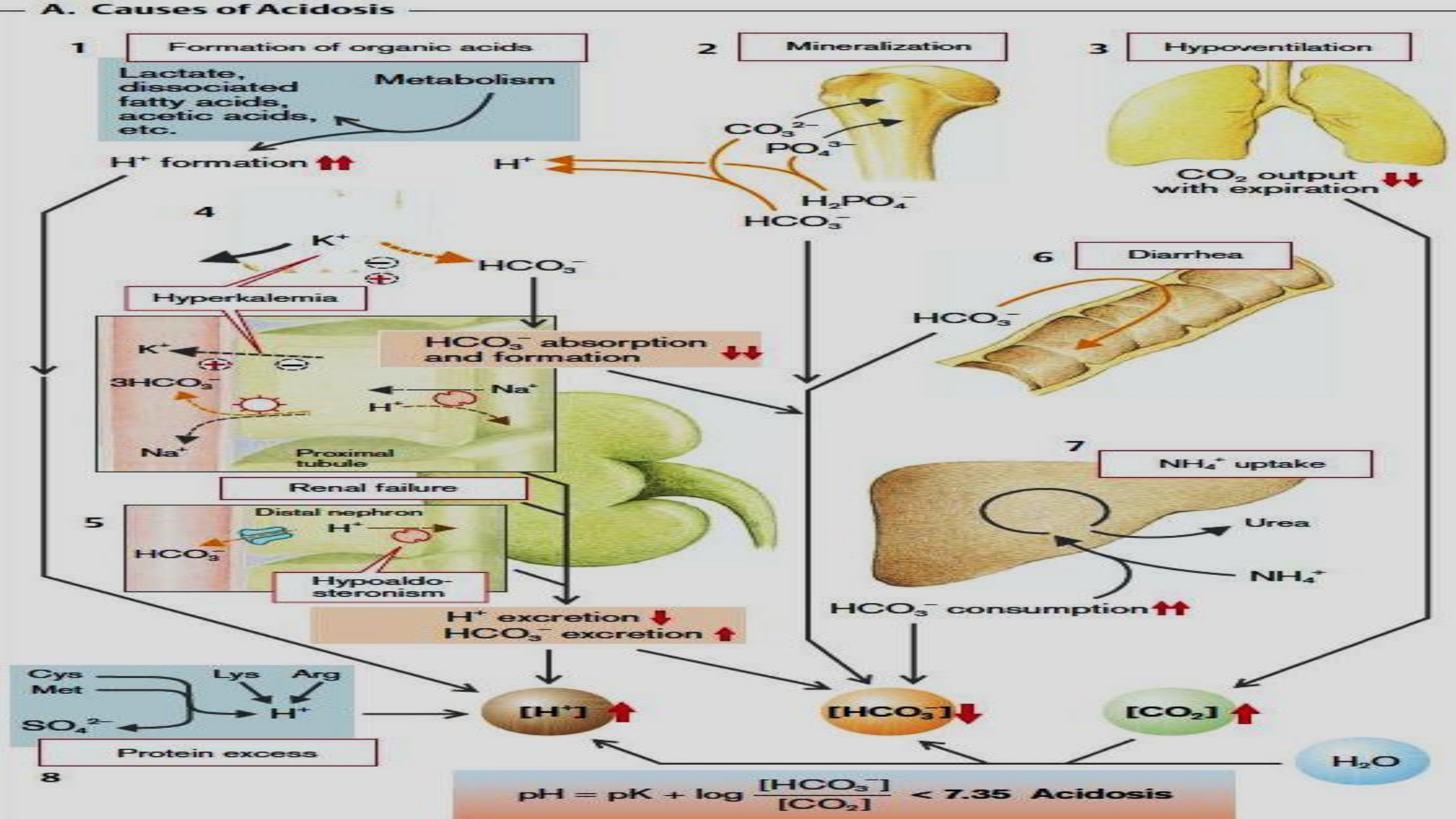
During metabolic acidosis HCO_3^- ↓, pH ↓ in plasma
compensatory pulmonary ventilation ↑ ,

CO_2 elimination ↑ → CO_2 ↓

Excretion of HCO_3^- by kidneys ↓

TABLE 32-2 Causes and Manifestations of Metabolic Acidosis

CAUSES	MANIFESTATIONS
Excess Metabolic Acids (Increased Anion Gap)	**Blood pH, HCO_3^-, CO_2**
Excessive production of metabolic acids	pH decreased
Lactic acidosis	HCO_3^- (primary) decreased
Diabetic ketoacidosis	PCO_2 (compensatory) decreased
Alcoholic ketoacidosis	**Gastrointestinal Function**
Fasting and starvation	Anorexia
Poisoning (*e.g.*, salicylate, methanol, ethylene glycol)	Nausea and vomiting
Impaired elimination of metabolic acids	Abdominal pain
Kidney failure or dysfunction	**Neural Function**
Excessive Bicarbonate Loss (Normal Anion Gap)	Weakness
Loss of intestinal secretions	Lethargy
Diarrhea	General malaise
Intestinal suction	Confusion
Intestinal or biliary fistula	Stupor
Increased renal losses	Coma
Renal tubular acidosis	Depression of vital functions
Treatment with carbonic anhydrase inhibitors	**Cardiovascular Function**
Hypoaldosteronism	Peripheral vasodilation
Increased Chloride Levels (Normal Anion Gap)	Decreased heart rate
Excessive reabsorption of chloride by the kidney	Cardiac arrhythmias
Sodium chloride infusions	**Skin**
Treatment with ammonium chloride	Warm and flushed
Parenteral hyperalimentation	**Skeletal System**
	Bone disease (*e.g.*, chronic acidosis)
	Signs of Compensation
	Increased rate and depth of respiration (*i.e.*, Kussmaul breathing)
	Hyperkalemia
	Acid urine
	Increased ammonia in urine


A. Causes of Acidosis
1
Formation of organic acids
Lactate, dissociated fatty acids, acetic acids, etc.
Metabolism
H+ formation
2
Mineralization
CO3 2–
PO4 3–
H+
H2PO4–
HCO3–
3
Hypoventilation
CO2 output with expiration
4
K+
HCO3–
Hyperkalemia
HCO3– absorption and formation
K+
3HCO3–
Na+
H+
Na+
Proximal tubule
Renal failure
5
Distal nephron
H+
HCO3–
Hypoaldo-steronism
H+ excretion
HCO3– excretion
6
Diarrhea
HCO3–
7
NH4+ uptake
Urea
NH4+
HCO3– consumption
Cys
Met
Lys
Arg
H+
SO4 2–
Protein excess
8
[H+]
[HCO3–]
[CO2]
H2O
pH = pK + log [HCO3–] / [CO2] < 7.35 Acidosis

During hypokalemia, secretion of H+ ions and reabsorption of HCO_3^- ions are observed.

In hypokalemia, K+ moves from → intercellular space to → extracellular space

In contrast, H+ → ions ESS →ISS.

A similar process occurs in the distal tubules of the kidney.

Acidosis→ H+ elimination ↑ and K+ elimination ↓ → hyperkalemia

Alkalosis → H+ elimination ↓, K+ elimination

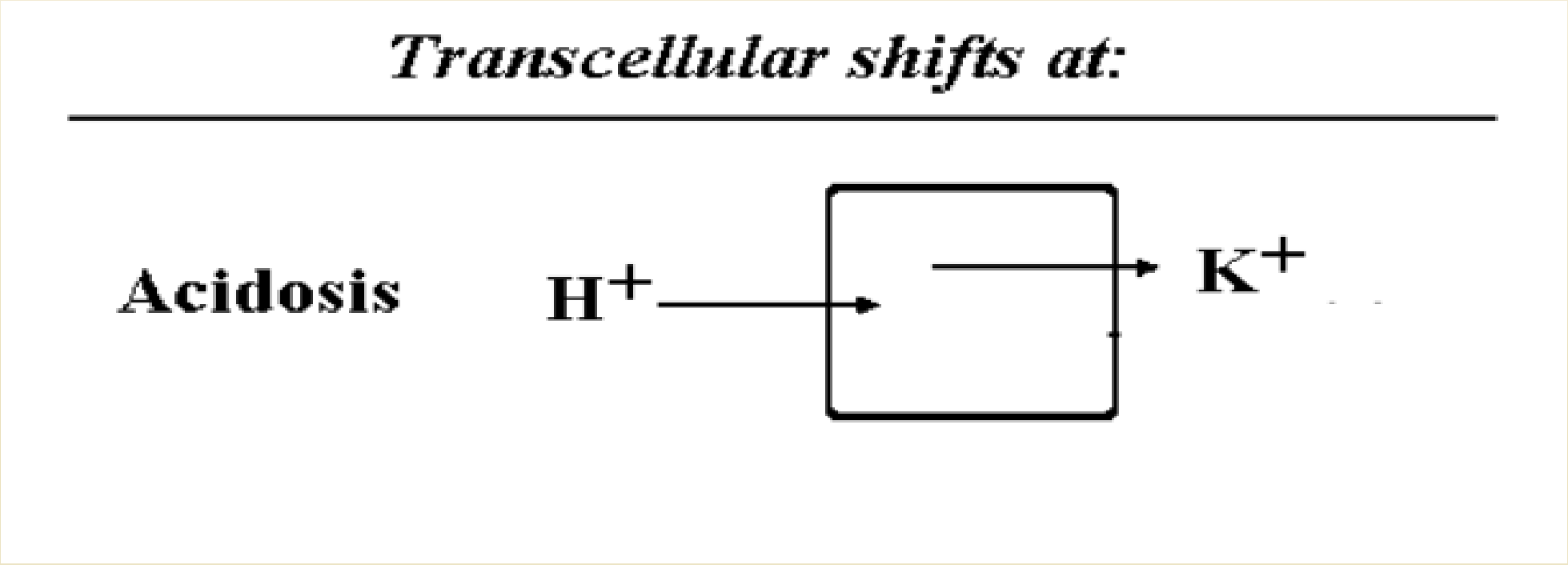
Normally, Cl- ions are reabsorbed along with Na+ in the renal tubule.

When vomiting and chlorine depletion → blood volume ↓ → kidney replaces Cl− anion with HCO3− and → HCO3− reabsorption ↑ .

Hypochloremic alkalosis pH ↑,Cl↓ → HCO3 reabsorption↑.

Hyperchloremic acidosis → Cl ↑→ HCO3 reabsorption ↓.

During acidosis elimination of H+ ions ↑,
The elimination of K+ ions decreases,
resulting in plasma K+↑



During metabolic alkalosis plasma HCO_3 ↑ and pH ↑

During compensasion pulmonary ventilation ↓

CO_2 elimination ↓ → CO_2↑

HCO_3 excretion by the kidneys ↑

Causes of metabolic alkalosis

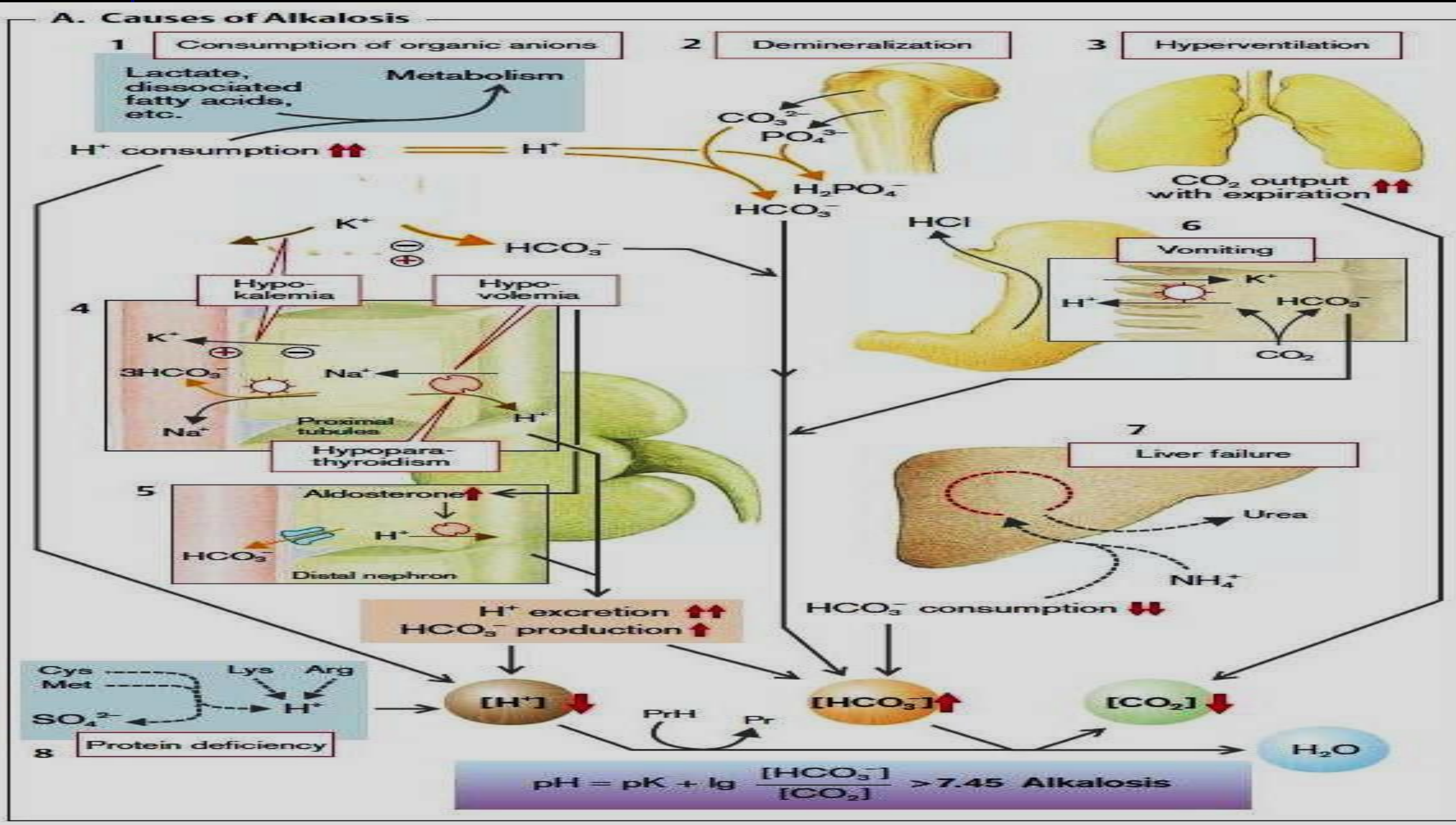
• loss of acidic stomach contents (hypochloremia), vomiting,during aspiration of acidic stomach contents through probes

• long-term use of diuretics

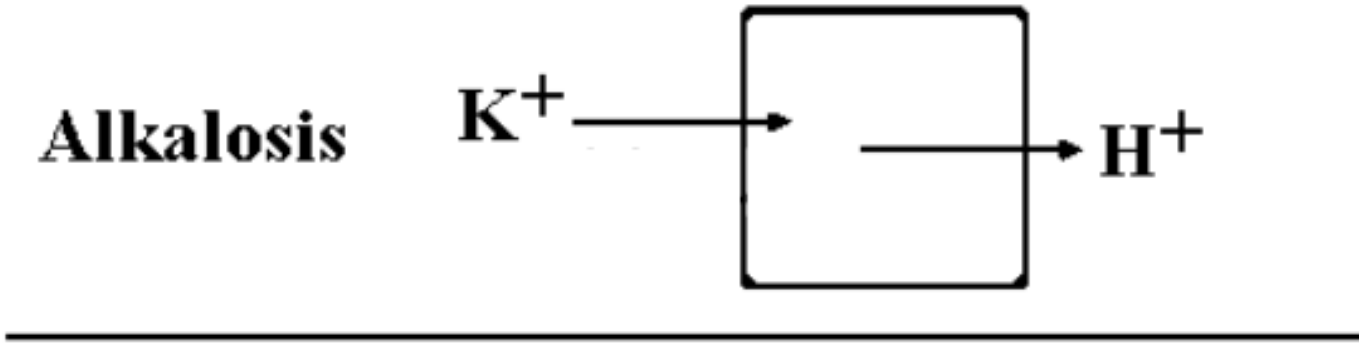
• increased excretion of hydrogen ions through the kidneys.

TABLE 32-3 Causes and Manifestations of Metabolic Alkalosis

CAUSES	MANIFESTATIONS
Excessive Gain of Bicarbonate or Alkali	**Blood pH, HCO_3^-, CO_2**
Ingestion or administration of sodium bicarbonate	pH increased
Administration of hyperalimentation solutions containing acetate	HCO_3^- (primary) increased
Administration of parenteral solutions containing lactate	PCO_2 (compensatory) increased
Administration of citrate-containing blood transfusions	**Neural Function**
Excessive Loss of Hydrogen Ions	Confusion
Vomiting	Hyperactive reflexes
Gastric suction	Tetany
Binge-purge syndrome	Convulsions
Potassium deficit	**Cardiovascular Function**
Diuretic therapy	Hypotension
Hyperaldosteronism	Arrhythmias
Milk-alkali syndrome	**Respiratory Function**
Increased Bicarbonate Retention	Respiratory acidosis due to decreased respiratory rate
Loss of chloride with bicarbonate retention	**Signs of Compensation**
Volume Contraction	Decreased rate and depth of respiration
Loss of body fluids	Increased urine pH
Diuretic therapy	


A. Causes of Alkalosis
1
Consumption of organic anions
Lactate, dissociated fatty acids, etc.
Metabolism
H+ consumption
2
Demineralization
CO3 2–
PO4 3–
H+
H2PO4–
HCO3–
3
Hyperventilation
CO2 output with expiration
K+
HCO3–
Hypo-kalemia
Hypo-volemia
4
K+
3HCO3–
Na+
Na+
H+
Proximal tubulee
Hypopara-thyroidism
5
Aldosterone
H+
HCO3–
Distal nephron
HCl
6
Vomiting
K+
H+
HCO3–
CO2
7
Liver failure
Urea
NH4+
H+ excretion
HCO3– production
HCO3– consumption
Cys
Met
Lys
Arg
SO4 2–
H+
8
Protein deficiency
[H+]
[HCO3–]
[CO2]
PrH
Pr
H2O
pH = pK + lg [HCO3–] / [CO2] >7.45 Alkalosis

During alkalosis H+ elimination ↓
K+ excretion ↑, resulting in plasma K+↓



In alkalosis, the body loses Cl−.

HCO3− reabsorption from the kidney increases↑.

İn hypochloremic alkalosis → blood pH ↑

Vomiting

Cl^- depletion

Extracellular fluid depletion

K^+ depletion

Decreased GFR

↓ HCO_3^- filtration

↑ Renin release

↑ Aldosterone secretion

↑ HCO_3^- reabsorption

↑ HCO_3^- reabsorption

↑ HCO_3^- reabsorption

Alkalosis

- Vomiting

- loss of K+ and Cl- from organism

- Loss of volume ⟹ activation of aldosterone

İn respiratory acidosis or hypercapnia blood PCO2-↑, plasma pH ↓

During compensation HCO3 is stored in the body → HCO3 ↑

H+- elimination of kidneys ↑

Acid-Base Imbalance	Primary Disturbance	Respiratory Compensation	Renal Compensation
Metabolic acidosis	Decrease in bicarbonate	Hyperventilation to decrease PCO_2	If no renal disease, increased H^+ excretion and increased HCO_3^- reabsorption
Metabolic alkalosis	Increase in bicarbonate	Hypoventilation to increase PCO_2	If no renal disease, decreased H^+ excretion and decreased HCO_3^- reabsorption
Respiratory acidosis	Increase in PCO_2	None	Increased H^+ excretion and increased HCO_3^- reabsorption
Respiratory alkalosis	Decrease in PCO_2	None	Decreased H^+ excretion and decreased HCO_3^- reabsorption

TABLE 32-4 Causes and Manifestations of Respiratory Acidosis

CAUSES	MANIFESTATIONS
Depression of Respiratory Center	**Blood pH, CO_2, HCO_3^-**
Drug overdose	pH decreased
Head injury	PCO_2 (primary) increased
Lung Disease	HCO_3^- (compensatory) increased
Bronchial asthma	**Neural Function**
Emphysema	Dilation of cerebral vessels and depression of neural function
Chronic bronchitis	Headache
Pneumonia	Weakness
Pulmonary edema	Behavior changes
Respiratory distress syndrome	Confusion
Airway Obstruction, Disorders of Chest Wall and Respiratory Muscles	Depression
Paralysis of respiratory muscles	Paranoia
Chest injuries	Hallucinations
Kyphoscoliosis	Tremors
Extreme obesity	Paralysis
Treatment with paralytic drugs	Stupor and coma
Breathing Air With High CO_2 Content	**Skin**
	Skin warm and flushed
	Signs of Compensation
	Acid urine

During respiratory alkalosis or hypocapnia blood $PCO_2\downarrow$, plasma pH↑

İn compensation HCO_3 elimination ↑→HCO_3 ↓,

H^+ excretion ↓

TABLE 32-5 Causes and Manifestations of Respiratory Alkalosis

CAUSES	MANIFESTATIONS
Excessive Ventilation	**Blood pH, CO_2, HCO_3^-**
Anxiety and psychogenic hyperventilation	pH increased
Hypoxia and reflex stimulation of ventilation	PCO_2 (primary) decreased
Lung disease that causes a reflex stimulation of ventilation	HCO_3^- (compensatory) decreased
Stimulation of respiratory center	**Neural Function**
Elevated blood ammonia level	Constriction of cerebral vessels and increased neuronal excitability
Salicylate toxicity	Dizziness, panic, lightheadedness
Encephalitis	Tetany
Fever	Numbness and tingling of fingers and toes
Mechanical ventilation	Positive Chvostek and Trousseau signs
	Seizures
	Cardiovascular Function
	Cardiac arrhythmias

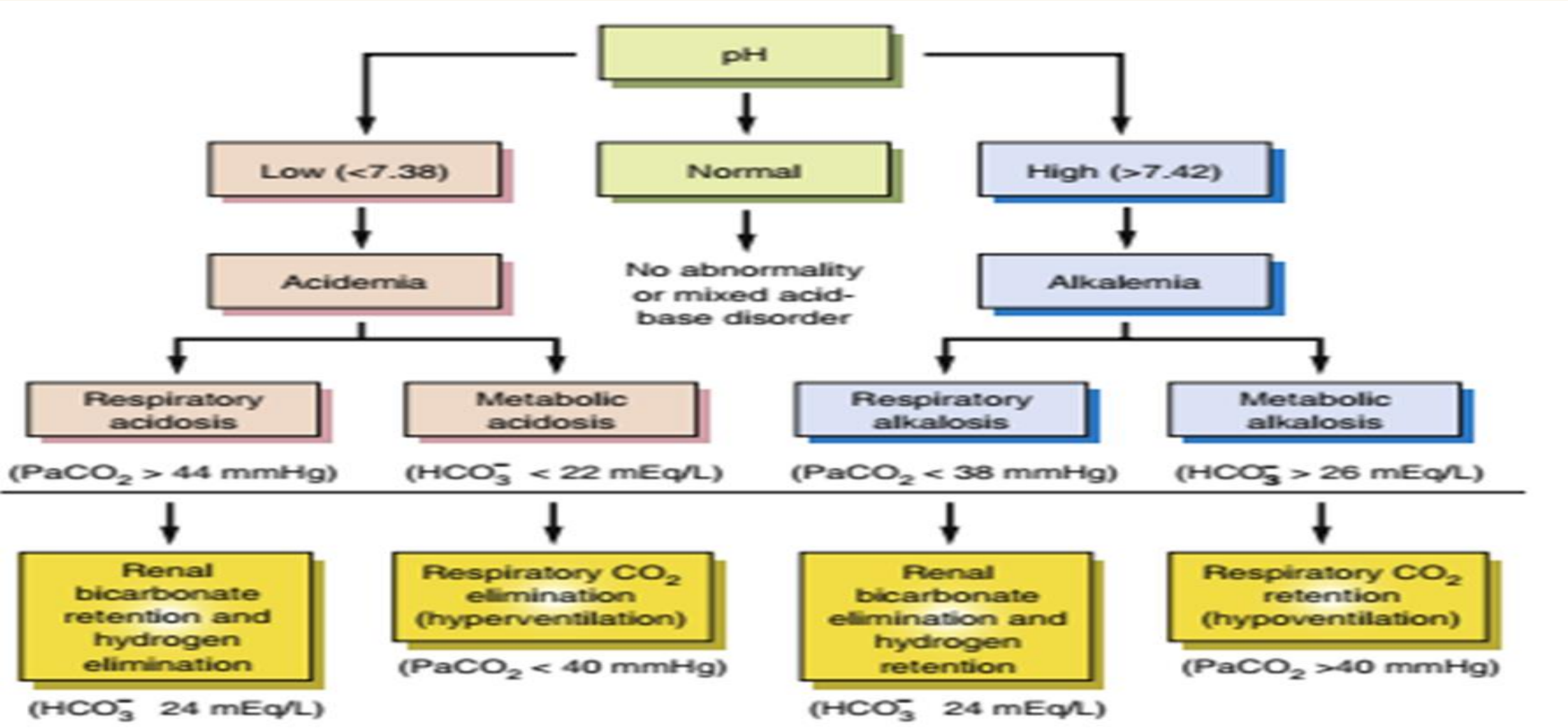
Respiratory acidosis is compensated by metabolic alkalosis

Respiratory alkalosis is compensated by metabolic acidosis.

Metabolic acidosis is compensated by respiratory alkalosis.

Metabolic alkalosis is compensated by respiratory acidosis.

Acid-base changes and its compensatory



Gas content of blood

* blood pH - norm 7.35-7.45;
* pCO2 in blood – norm 35.0-45.0 mm Hg.
* pO2 in blood - norm 37-42 mm Hg.
* saturation of O2 - 95-100%
* Na+ -- norm 136.0-146.0 mmol/l.;
* K+ - norm 3.4-4.5 mmol/l,;
* Ca++ - norm 1.15-1.29 mmol/l;
* SB (Standard Bicarbonate) – norm 22-26 mmol/l;
* BB (Buffer Base) – norm 40-48 mmol/l.
* BE (Base Excess) - norm ±3.5 mmol/l.

. **İndications for the analysis of gas content of arterial blood:**

- Diagnosis of metabolic and respiratory acidosis and alkalosis
- Determination of the type of respiratory failure
- Instruction for oxygen therapy
- study of shortness of breath

* **pO2 in arterial blood is normally 80-100 mm Hg. if taken:**

Pa O2 60-79 mm Hg. between → mild hypoxemia;
PaO2 40-59 mm Hg. between → moderate hypoxemia;
PaO2 < 40 mm Hg. → called severe hypoxemia.

Standard bicarbonate: Under standard conditions (when the temperature is -37°C and PCO2-40 mm Hg) is the bicarbonate value in the blood.

Normally it is 22-26 mev/l.

***True Bicarbonate**: The actual bicarbonate in the bloodis the value.

Normally 22-26 mev/L.

HCO3 >26 = Alkalosis

HCO3 <22 = Acidosis

If standard bicarbonate is less than actual bicarbonate → **respiratory acidosis**,

If standard bicarbonate is greater than actual bicarbonate → **respiratory alkalosis**

If standard bicarbonate is equal to actual bicarbonate, but less than normal → **decompensated metabolic acidosis**

If the standard bicarbonate equals the actual bicarbonate, but exceeds the norm → **decompensated metabolic alkalosis**

***BE (Base Excess-alkaline excess):**temperature 37ºC and pCO2 40 mm Hg which is the amount of acid or base required to raise the pH of fully oxygenated blood to 7.40.

The normal value of BE is ±2.5 mmol/l.

BE < 2.5 =metabolic acidosis

BE >2.5 =metabolic alkalosis

*__Alveolar-arterial oxygen gradient__:

It is the difference between the partial pressure of oxygen in the alveolar air and paO2.
Normally 5 mm.Hg
After 20 years of age every 10 years increases 4 mm.Hg

* Measurement of arterial blood pH
* Determination of acidosis and alkalosis

Na+, K+, H+, Cl– etc.In serum, Na+ and K+ ions account for 95% of cations,

Cl- and HCO3 ions make up about 85% of the anions.

*Anion gap study (AG)

Plasma anion gap → is the difference between anions and cations. (Na++ K) - (CI- +HCI3)→(142+4) - (106+24)=8-16 mev/l,

Na - HCO3 - CI= 8-16 mev/l,

Anion gap ↑→metabolic acidosis

If CI- ions in the plasma increase in proportion to the decrease in HCO3, the anion gap is normal, this is hyperchloremic metabolic acidosis.

If metabolic acidosis is due to non-volatile acid → anion gap ↑. Because the decrease of HCO3- ions was not proportional to the increase of CI- ions.

CHART 32-1

THE ANION GAP IN DIFFERENTIAL DIAGNOSIS OF METABOLIC ACIDOSIS

Decreased Anion Gap (<8 mEq/L)

Hypoalbuminemia (decrease in unmeasured anions)
Multiple myeloma (increase in unmeasured cationic IgG paraproteins)
Increased unmeasured cations (hyperkalemia, hypercalcemia, hypermagnesemia, lithium intoxication)

Increased Anion Gap (>12 mEq/L)

Presence of unmeasured metabolic anion
- Diabetic ketoacidosis
- Alcoholic ketoacidosis
- Lactic acidosis
- Starvation
- Renal insufficiency

Presence of drug or chemical anion
- Salicylate poisoning
- Methanol poisoning
- Ethylene glycol poisoning

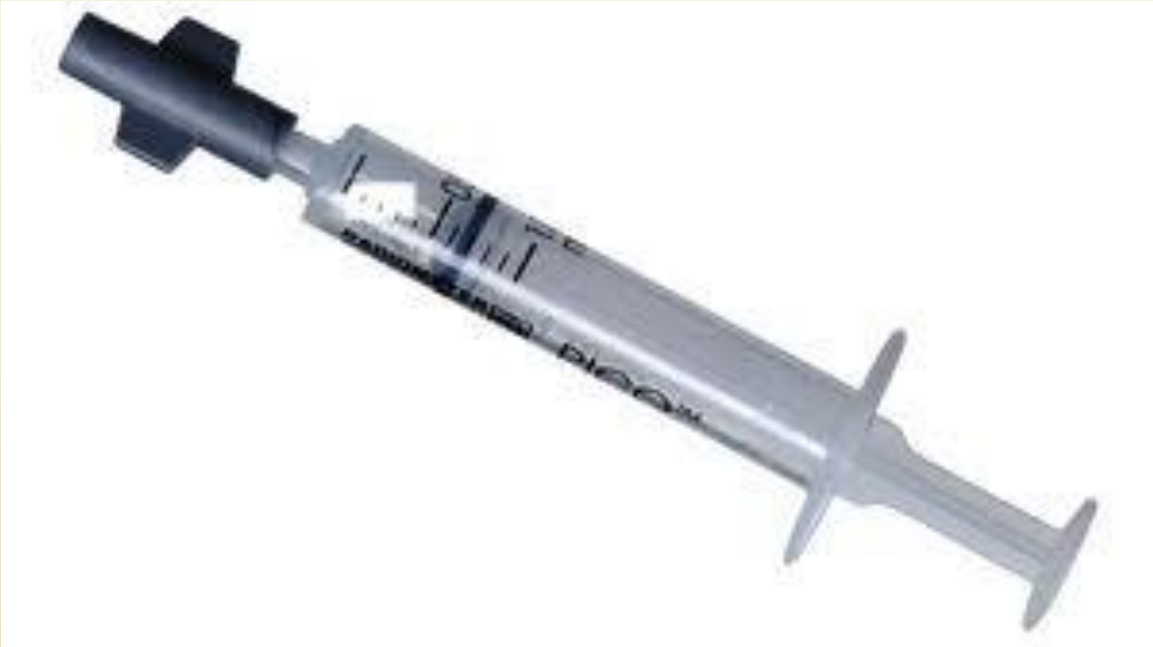
Normal Anion Gap (8—12 mEq/L)

Loss of bicarbonate
- Diarrhea
- Pancreatic fluid loss
- Ileostomy (unadapted)

Chloride retention
- Renal tubular acidosis
- Ileal loop bladder
- Parenteral nutrition (arginine and lysine)

In modern times, blood sampling for the study of acid-alkaline balance is carried out using a PICO sampler, which provides high analytical quality.

*PICO sampler. Contains antithrombotic electrolyte balanced dry heparin. PICO50: Self-filling with 2 ml of blood. This radiometer is manufactured by Medical ApS, Denmark.



* ABL800FLEX blood gas analyzer. Measure osmotic pressure in body fluids OSMO STATION OM-6060-Made in Japan

THANK YOU FOR

YOUR ATTENTION