Arterial Blood Gas Analysis

Dr Umar

Overview

- ABG Sampling
- Interpretation of ABG
  - Gas Exchange
  - Acid Base status

Applications of ABG

- To document respiratory failure and assess its severity
- To monitor patients on ventilators and assist in weaning
- To assess acid base imbalance in critical illness
- To assess response to therapeutic interventions and mechanical ventilation
- To assess pre-op patients

ABG – Procedure and Precautions

Where to place -- the options

Radial

Dorsalis Pedis

Femoral

Brachial

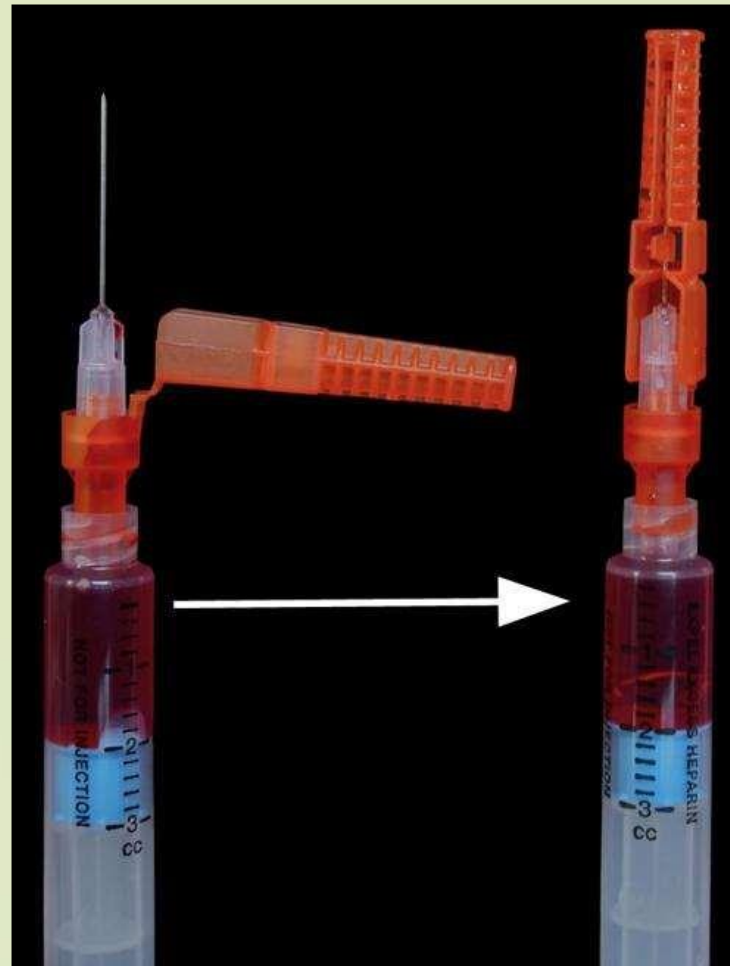
Technical Errors

Excessive Heparin

- Ideally : Pre-heparinised ABG syringes
- Syringe **FLUSHED** with 0.5ml 1:1000 Heparin & emptied
- **DO NOT LEAVE EXCESSIVE HEPARIN IN THE SYRINGE**

↑ HEPARIN ↑ DILUTIONAL EFFECT ↓ HCO_3^- ↓ pCO_2

ABG Syringe



Technical Errors

- Risk of alteration of results ↑ with:
  - 1)↑ **size** of syringe/needle
  - 2)↓ **vol** of sample

- ✓ Syringes must have > 50% blood
- ✓ Use only 3ml or less syringe
- ✓ 25% lower values if 1 ml sample taken in 10 ml syringe (0.25 ml heparin in needle)

Technical Errors

Air Bubbles

- pO_2 150 mm Hg & pCO_2 0 mm Hg
  - **Contact with AIR BUBBLES**

    ↑ **pO2** & ↓ **pCO2**

- Seal syringe immediately after sampling

Body Temperature

- Affects values of $\mathbf{pCO_2}$ and $\mathbf{HCO_3^-}$ only
- ABG Analyser controlled for Normal Body temperatures

Technical Errors

WBC Counts

- 0.01 ml O_2 consumed/dL/min
- Marked increase in high TLC/plt counts : ↓ **pO2**
- Chilling / immediate analysis

ABG Syringe must be transported earliest via COLD CHAIN

Change/10 min	Uniced 37^0C	Iced 4^0C
pH	0.01	0.001
pCO_2	1 mm Hg	0.1 mm Hg
pO_2	0.1%	0.01%

ABG Equipment

- **3 electrode system** that measures three fundamental variables - **pO_2, pCO_2** and **pH**
- All others parameters such as HCO_3^- computed by software using standard formulae

Interpretation of ABG

- ❑ Gas exchange
- ❑ Acid Base Status

Gas exchange

Assessment Of Gas exchange

- PaO_2 vs SpO_2
- Alveolar-arterial O_2 gradient
- PaO_2/FiO_2 ratio
- $PaCO_2$

Determinants of PaO_2

PaO_2 is dependant upon ⟹ Age, FiO_2, P_{atm}

As **Age** ↑ the expected **PaO_2** ↓

- $PaO_2 = 109 - 0.4\,(Age)$

As **FiO_2** ↑ the expected **PaO_2** ↑

- Alveolar Gas Equation:
  - $P_AO_2 = (P_B - P_{H_20}) \times FiO_2 - pCO_2/R$

Hypoxemia

- Normal PaO_2 : 95 – 100 mm Hg
- Mild Hypoxemia : PaO_2 60 – 80 mm Hg
- Moderate Hypoxemia : PaO_2 40 – 60 mm Hg – tachycardia, hypertension, cool extremities
- Severe Hypoxemia : $PaO_2 < 40$ mm Hg – severe arrhythmias, brain injury, death

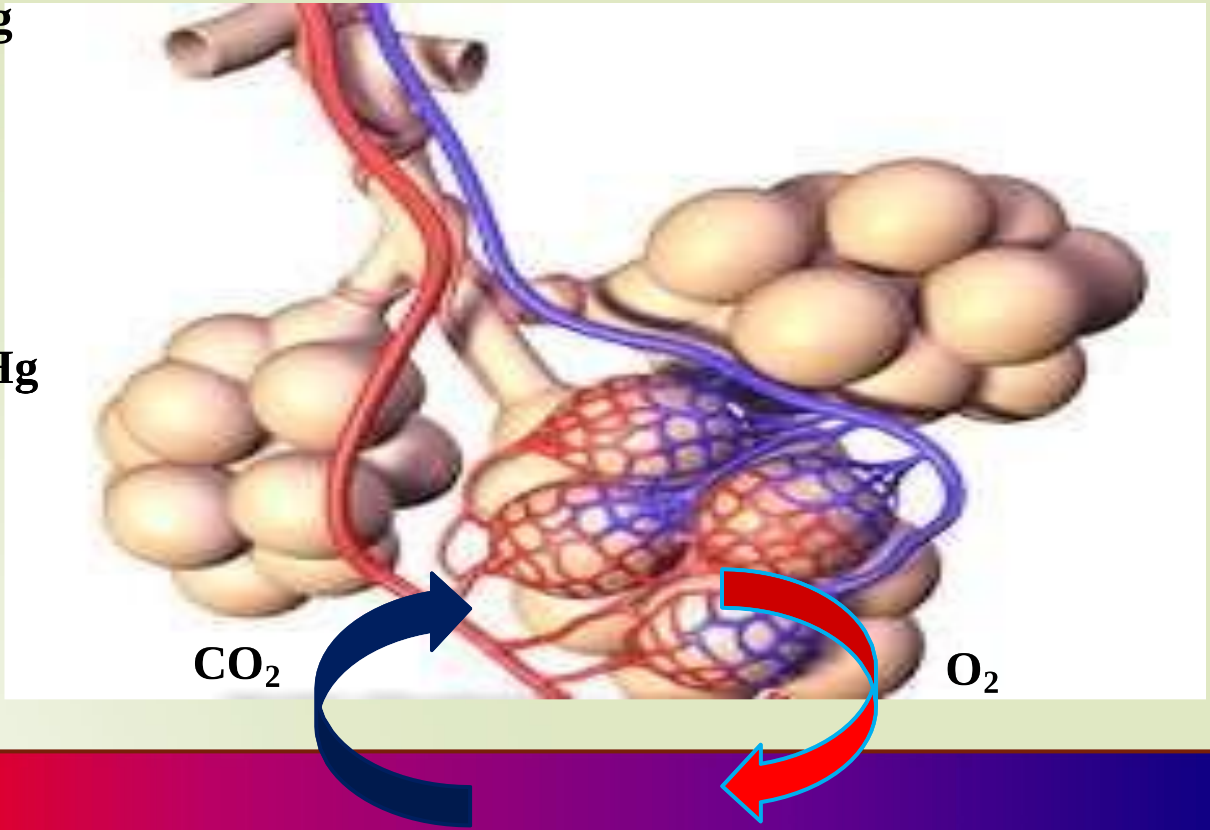
Alveolar-arterial O_2 gradient

- $P(A\text{-}a)O_2$ is the alveolar-arterial difference in partial pressure of oxygen
- $PAO_2 = 150 – PaCO_2/RQ$
- Normal range : 5 - 25 mm Hg (increases with age)
- Increase $P(A\text{-}a)O_2$: lung parenchymal disease

PaO_2 / FiO_2 ratio

Inspired Air $FiO_2 = 21\%$
$PiO_2 = 150$ mmHg

$P_{alv}O_2 = 100$ mmHg



$PaO_2 = 90$ mmHg

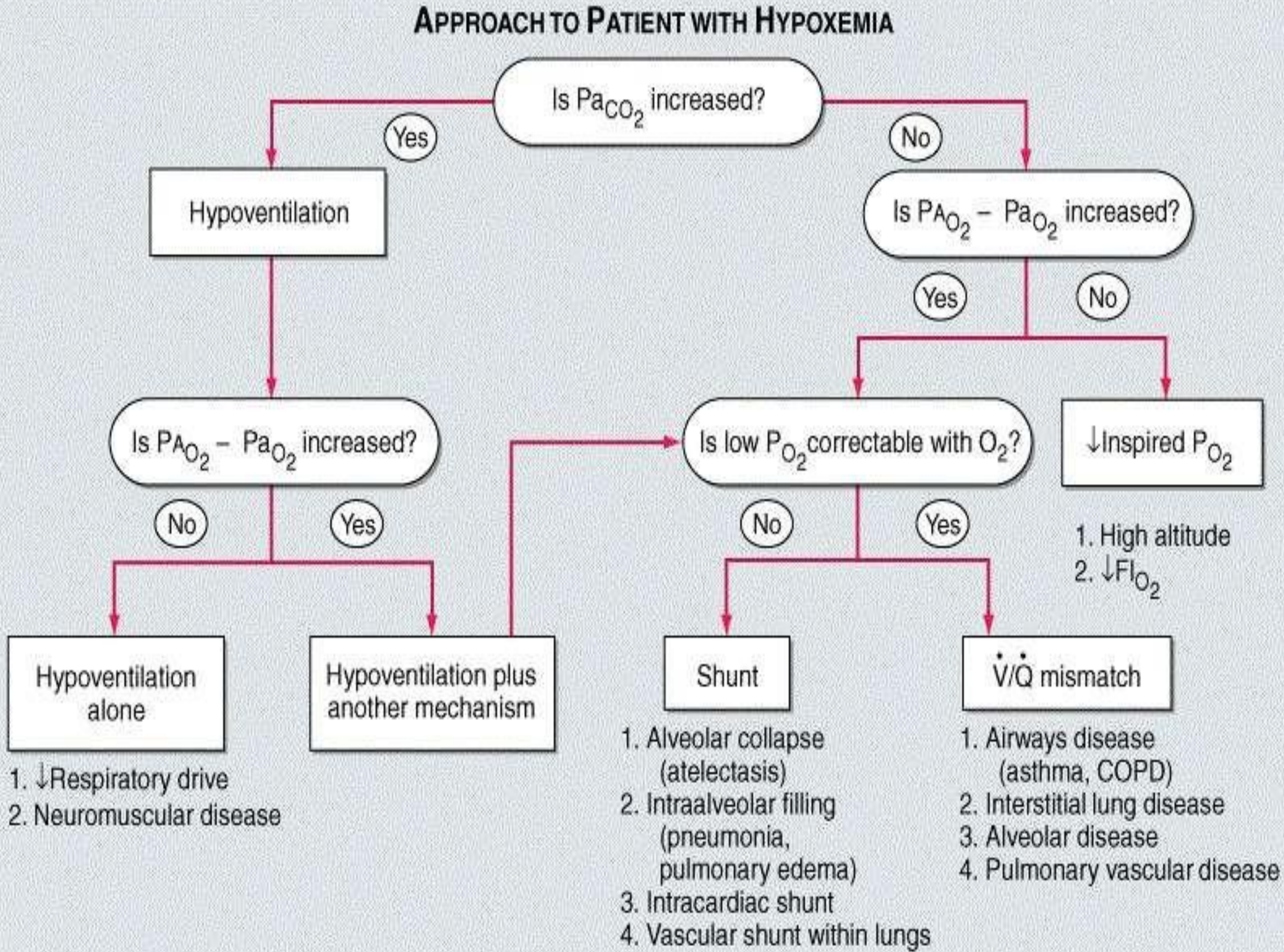
Berlin criteria for ARDS severity

***PaO_2 / FiO_2* ratio**	**Inference**
200 - 300 mm Hg	Mild ARDS
100 - 200 mm Hg	Moderate ARDS
< 100 mm Hg	Severe ARDS

ARDS is characterized by an acute onset within 1 week, bilateral radiographic pulmonary infiltrates, respiratory failure not fully explained by heart failure or volume overload, and a PaO_2/FiO_2 ratio < 300 mm Hg

Hypercapnia

- $PaCO_2$ is directly proportional to CO_2 production and inversely proportional to alveolar ventilation
- Normal $PaCO_2$ is 35 – 45 mm Hg


APPROACH TO PATIENT WITH HYPOXEMIA
Is Pa_{CO_2} increased?
Yes
No
Hypoventilation
Is $PA_{O_2} - Pa_{O_2}$ increased?
Yes
No
Is $PA_{O_2} - Pa_{O_2}$ increased?
No
Yes
Is low P_{O_2} correctable with O_2?
↓Inspired P_{O_2}
No
Yes
1. High altitude
2. ↓FI_{O_2}
Hypoventilation alone
Hypoventilation plus another mechanism
Shunt
V̇/Q̇ mismatch
1. ↓Respiratory drive
2. Neuromuscular disease
1. Alveolar collapse (atelectasis)
2. Intraalveolar filling (pneumonia, pulmonary edema)
3. Intracardiac shunt
4. Vascular shunt within lungs
1. Airways disease (asthma, COPD)
2. Interstitial lung disease
3. Alveolar disease
4. Pulmonary vascular disease

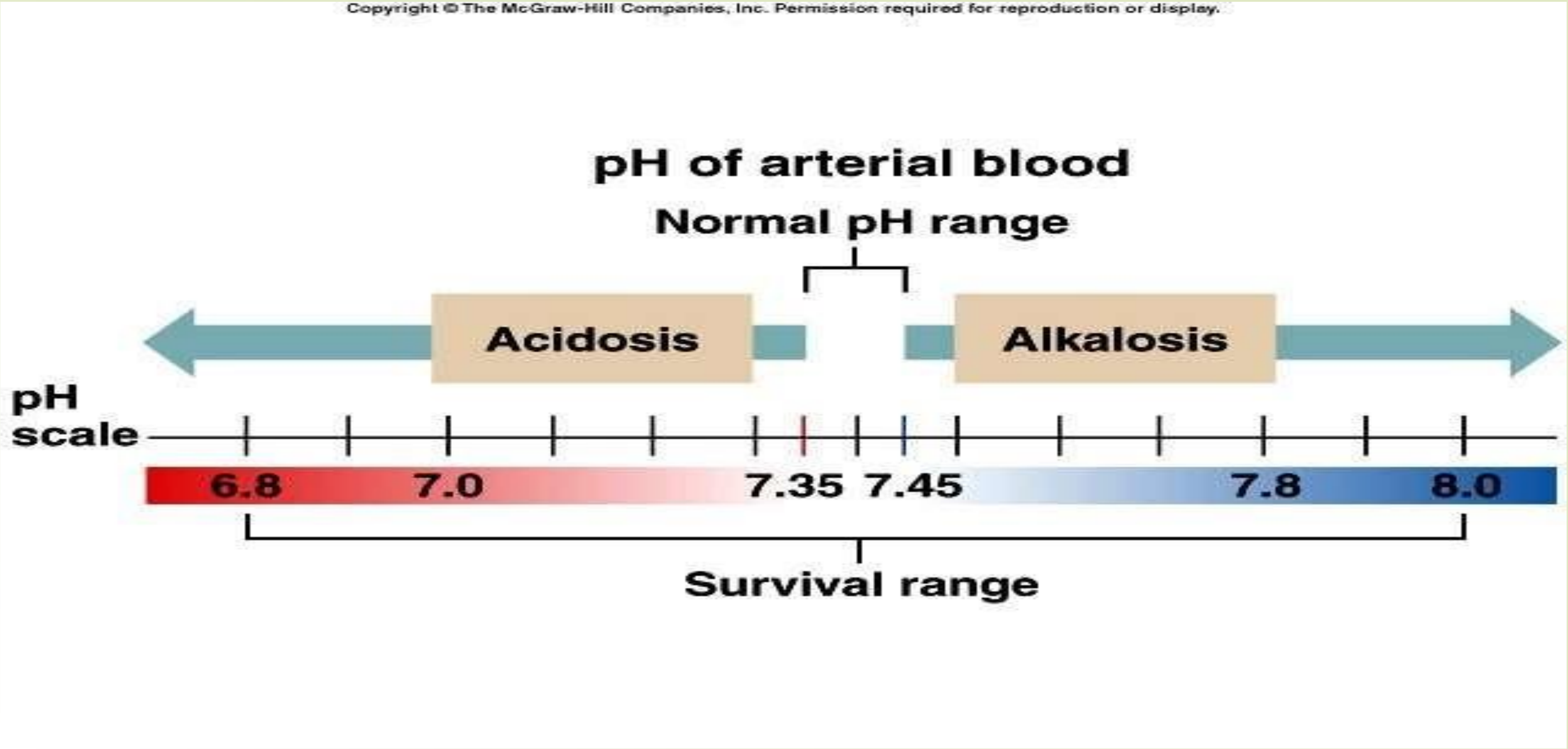
Acid Base Status

Basics

- Nano equivalent $=1\times10^{-9}$

  pH = -log [H⁺] : Sorensen formula

- $[H^+]$ = 40 nEq/L (16 to 160 nEq/L) at pH-7.4



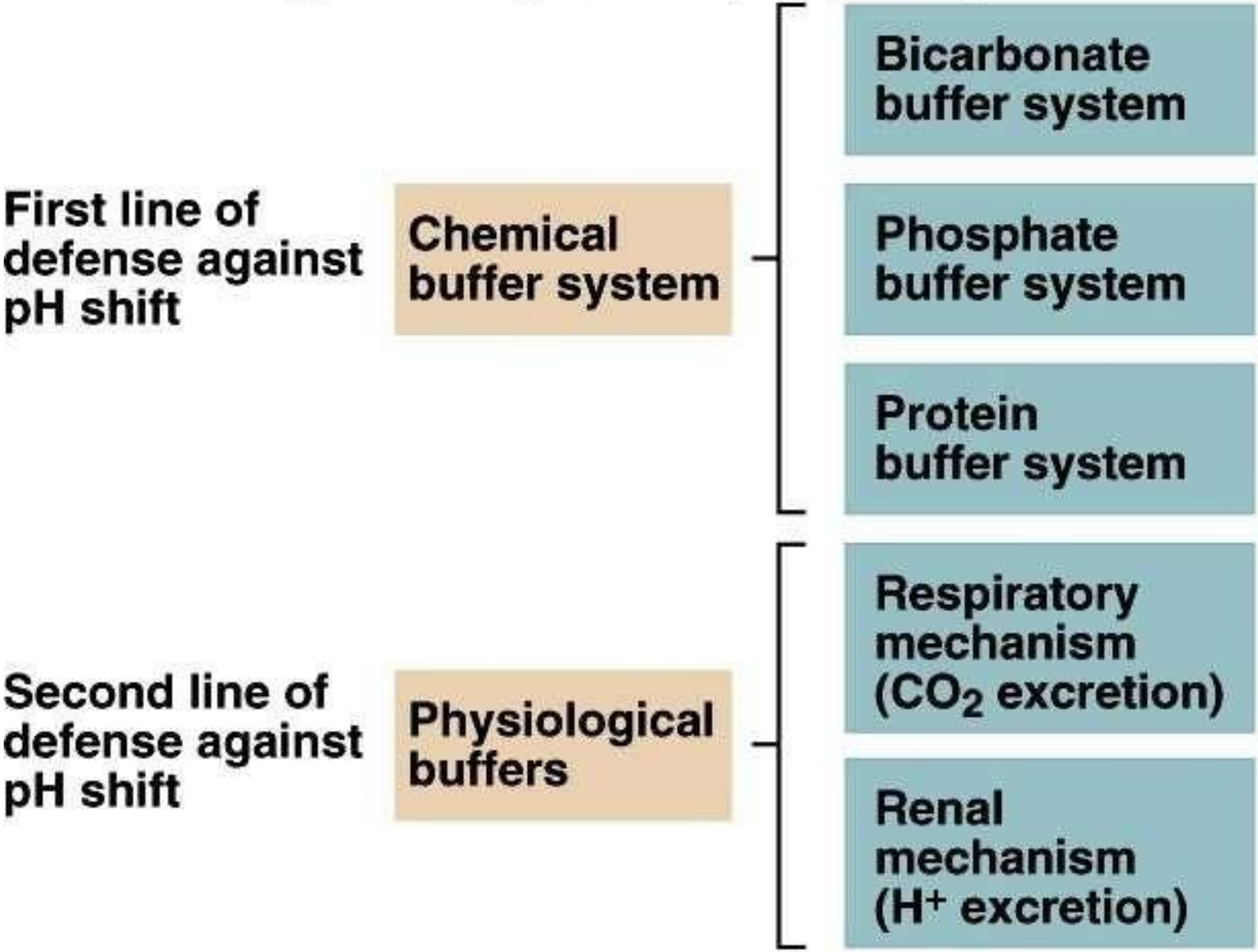
Henderson-Hasselbalch Equation

- Correlates metabolic & respiratory regulations

$$pH = pK + \log \frac{HCO_3^-}{.03 \times [PaCO_2]}$$

- *Simplified*

$$pH \sim \frac{HCO_3^-}{PaCO_2}$$


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)

Bicarbonate Buffer System

$$CO_2 + H_2O \xleftrightarrow{\text{carbonic anhydrase}} H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

Acidosis : Acid = H^+

$$\uparrow H^+ + HCO_3^- \longrightarrow H_2CO_3 \longrightarrow CO_2 + H_2O$$

Alkalosis : Alkali + Weak Acid = H_2CO_3

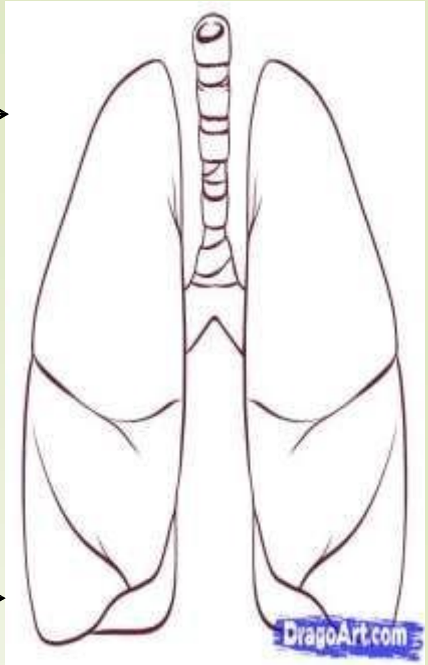
$$CO_2 + H_20 \longrightarrow H_2CO_3 \longrightarrow \uparrow HCO_3^- + H^+$$

$$+$$

Alkali

Respiratory Regulation

↑ H^+ ↔



ALVEOLAR VENTILATION ↑ ↔ $PaCO_2$ ↓

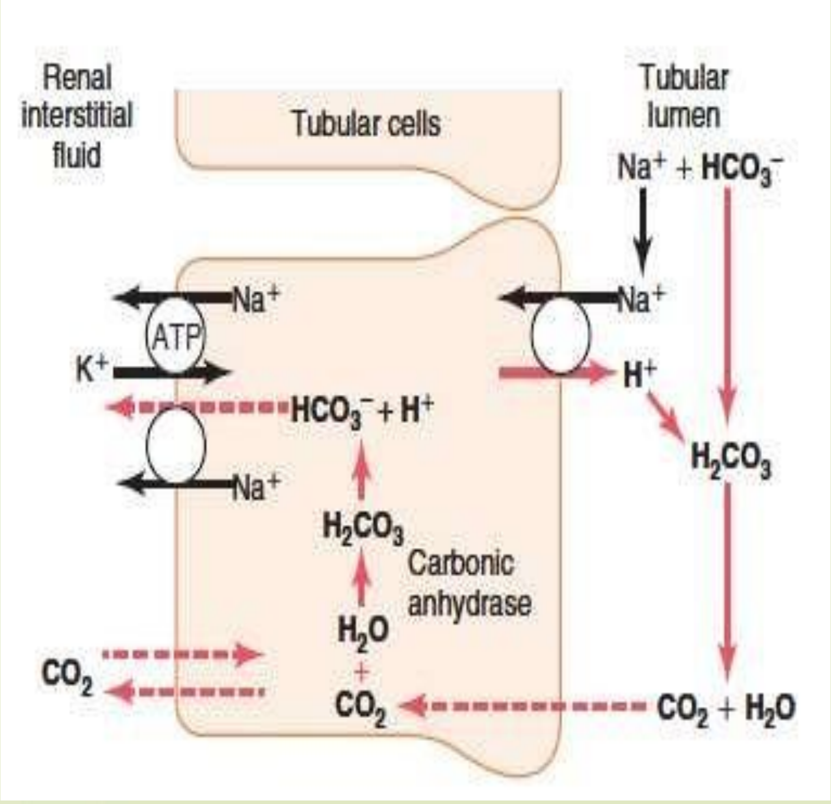
↓ H^+ ↔

ALVEOLAR VENTILATION ↓ ↔ $PaCO_2$ ↑

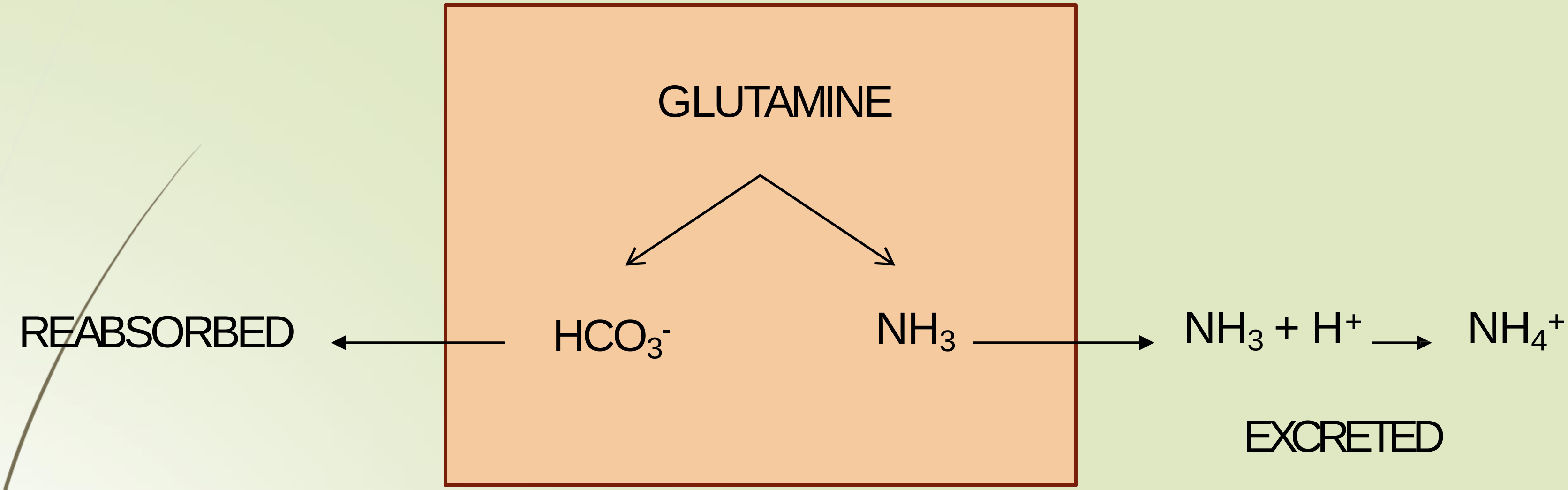
Renal Regulation

Kidneys control the acid-base balance by excreting either a basic or an acidic urine

- Excretion of HCO_3^-
- Regeneration of HCO_3^- with excretion of H^+



Excretion of excess H^+ & generation of new HCO_3^- : The Ammonia Buffer System



- In **chronic acidosis,** the dominant mechanism of acid eliminated **excretion of NH_4^+**

Response…

Bicarbonate Buffer System

- Acts in few seconds

Respiratory Regulation

- Starts within minutes good response by 2hrs, complete by 12-24 hrs

Renal Regulation

- Starts after few hrs, complete by 5-7 days

Abnormal Values

pH < 7.35

- Acidosis (metabolic and/or respiratory)

pH > 7.45

- Alkalosis (metabolic and/or respiratory)

$paCO_2$ > 45 mm Hg

- Respiratory acidosis (alveolar hypoventilation)

$paCO_2$ < 35 mm Hg

- Respiratory alkalosis (alveolar hyperventilation)

HCO_3^- < 22 meq/L

- Metabolic acidosis

HCO_3^- > 26 meq/L

- Metabolic alkalosis

Simple Acid-Base Disorders

Simple acid-base disorder – a single primary process of acidosis or alkalosis with or without compensation

Compensation…

The body always tries to normalize the pH so…

- pCO_2 and HCO_3^- rise & fall together in simple disorders
- Compensation never overcorrects the pH
- Lack of compensation in an appropriate time defines a 2nd disorder
- Require normally functioning lungs and kidneys

Characteristics of 1° acid-base disorders

DISORDER	PRIMARY RESPONSE			COMPENSATORY RESPONSE
Metaboli c acidosis	↑ $[H^+]$	↓ PH	↓ HCO_3^-	↓ pCO_2
Metaboli c alkalosis	↓ $[H^+]$	↑ PH	↑ HCO_3^-	↑ pCO_2
Respirato ry y acidosis	↑ $[H^+]$	↓ PH	↑ pCO2	↑ HCO_3^-
Respirato ry y	↓ $[H^+]$	↑ PH	↓ pCO2	↓ HCO_3^-

Disorder	Compensatory response
Respiratory acidosis	
Acute	↑ HCO_3^- 1 mEq/L per 10 mm Hg ↑ pCO_2
Chronic	↑ HCO_3^- 3.5 mEq/L per 10 mm Hg ↑ pCO_2
Respiratory alkalosis	
Acute	↓ HCO_3^- 2 mEq/L per 10 mm Hg ↓ pCO_2
Chronic	↓ HCO_3^- 5 mEq/L per 10 mm Hg ↓ pCO_2
Metabolic acidosis	↓ pCO_2 1.3 mm Hg per 1 mEq/L ↓ HCO_3^- (Limit of CO_2 is 10 mm Hg)
Metabolic alkalosis	↑ pCO_2 0.7 mm Hg per 1 mEq/L ↑ HCO_3^- (Limit of CO_2 is 55 mm Hg)

Mixed Acid-base Disorders

Presence of more than one acid base disorder simultaneously

Clues to a mixed disorder:

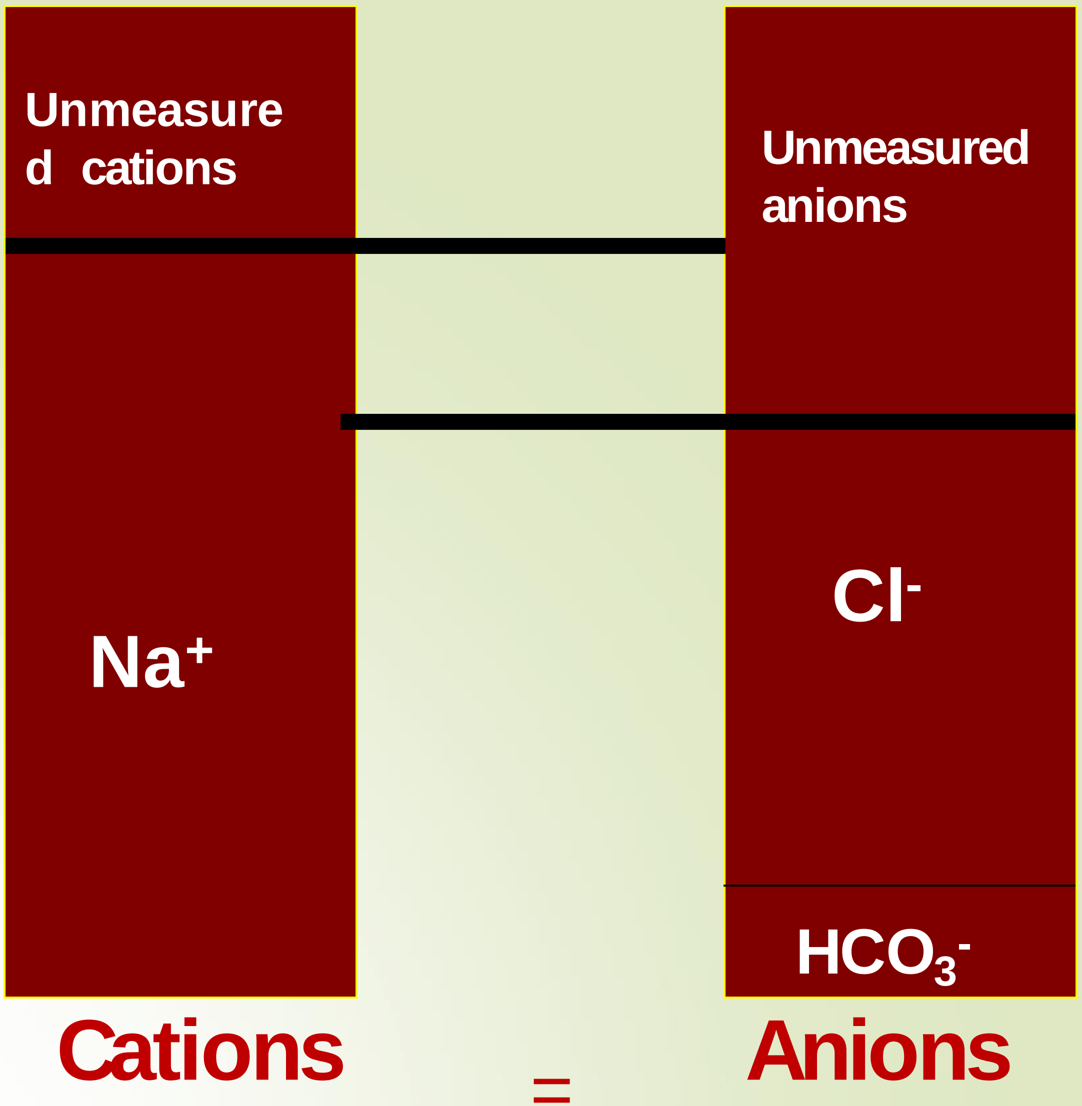
- Normal pH with abnormal HCO_3^- or pCO_2
- pCO_2 and HCO_3^- move in opposite directions
- pH changes in an opposite direction for a known primary disorder

Anion Gap

$$AG = [Na^+] - [Cl^- + HCO_3^-]$$

- Elevated anion gap represents metabolic acidosis
- Normal value: 12 ± 4 mEq/L
- Major unmeasured anions
  - albumin
  - phosphates
  - sulfates
  - organic anions

Anion Gap = Metabolic Acidosis



Increased Anion Gap

- Diabetic Ketoacidosis
- Chronic Kidney Disease
- Lactic Acidosis
- Alcoholic Ketoacidosis
- Aspirin Poisoning
- Methanol Poisoning
- Ethylene Glycol Poisoning
- Starvation

Normal Anion Gap

- Diarrhea
- Renal Tubular Acidosis
- Addisons Disease
- Carbonic Anhydrase Inhibitors

Delta Gap

- The difference between patient's AG & normal AG
- The coexistence of 2 metabolic acid-base disorders may be apparent

Delta gap = Anion gap – 12

Delta Gap + HCO_3^- = 22-26 mEq/l

- If >26, consider additional metabolic alkalosis
- If <22, consider additional non AG metabolic acidosis

STEP-BY-STEP ANALYSIS

OF

ACID-BASE STATUS

1. Look at the ***pO_2*** (<80 mm Hg) and ***O_2 saturation*** (<90%) for ***hypoxemia***

2. Look at the ***pH***

- < 7.35 : ACIDOSIS
- > 7.45 : ALKALOSIS
- 7.35 – 7.45 : normal/mixed disorder

3. Look at ***pCO_2***

- > 45 mm Hg : Increased (Acidic)
- < 35 mm Hg : Decreased (Alkalotic)

4. Look at the ***HCO_3^-***

- > 26 mEq/L : Increased (Alkalotic)
- < 22 mEq/L : Decreased (Acidic)

5. Determine the acid-base disorder, match either the pCO_2 or the HCO_3^- with the pH

6. ***Compensation***… are the CO_2 or HCO_3^- of opposite type ?

Is the compensation adequate??

METABOLIC DISORDER → **$PCO_{2expected}$**

- **PCO_2measured ≠ PCO_2expected** → MIXED DISORDER

RESPIRATORY DISORDER → **$pH_{expected}$**

- **pH_m ≠ pH_e range** → MIXED DISORDER

7. Calculate the ***anion gap*** if it is more there is Metabolic acidosis

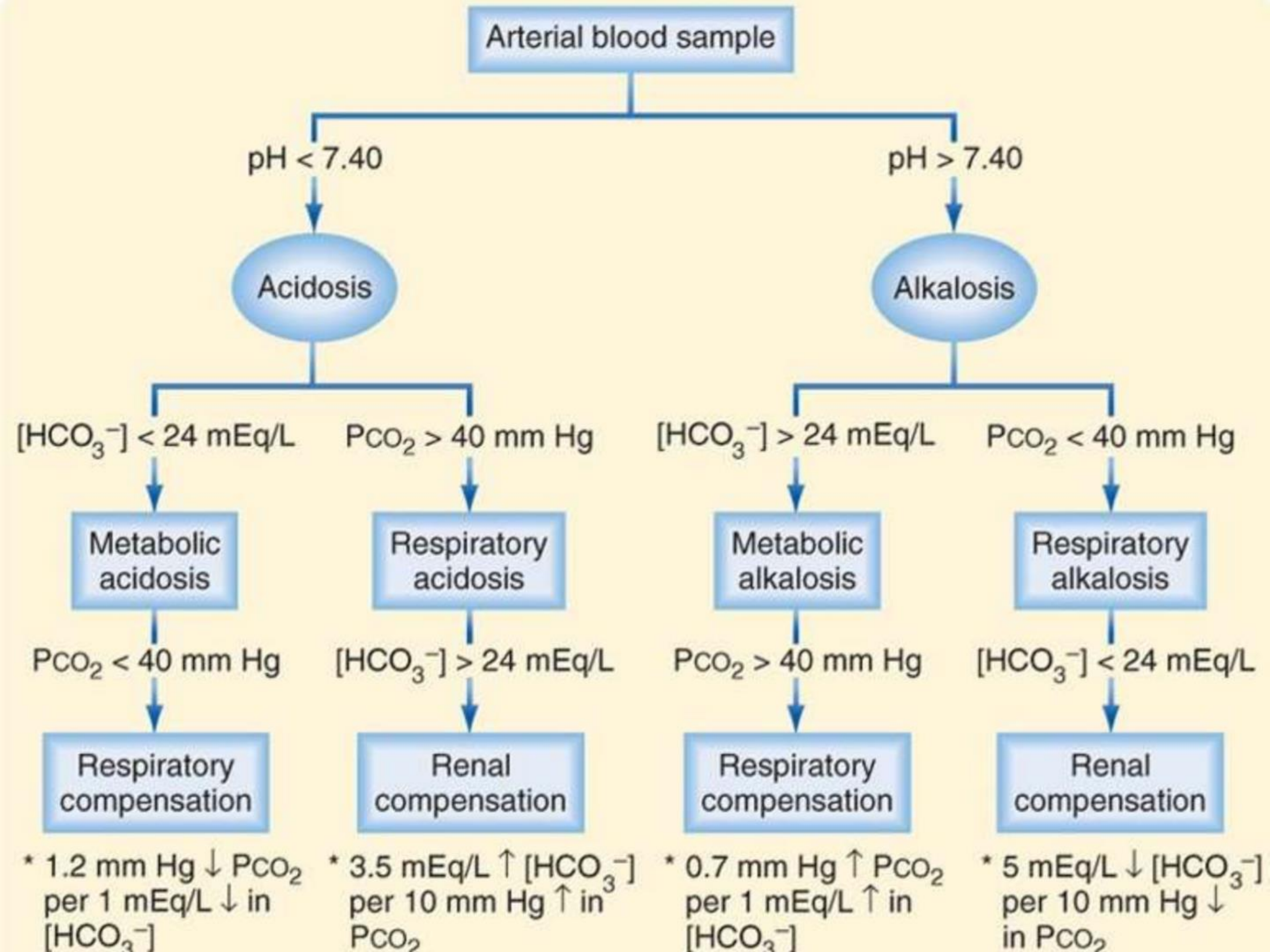
$$AG = [Na^+] - [Cl^- + HCO_3^-]$$

8. Does the anion gap explain the change in HCO_3^- *?*

Calculate ***Delta gap***

(rule out co-existence of 2 acid-base disorders)

9. Examine the patient to determine whether the clinical signs are compatible with the acid-base analysis…



Arterial blood sample
pH < 7.40
pH > 7.40
Acidosis
Alkalosis
[HCO3−] < 24 mEq/L
PCO2 > 40 mm Hg
[HCO3−] > 24 mEq/L
PCO2 < 40 mm Hg
Metabolic acidosis
Respiratory acidosis
Metabolic alkalosis
Respiratory alkalosis
PCO2 < 40 mm Hg
[HCO3−] > 24 mEq/L
PCO2 > 40 mm Hg
[HCO3−] < 24 mEq/L
Respiratory compensation
Renal compensation
Respiratory compensation
Renal compensation
* 1.2 mm Hg ↓ PCO2 per 1 mEq/L ↓ in [HCO3−]
* 3.5 mEq/L ↑ [HCO3−] per 10 mm Hg ↑ in PCO2
* 0.7 mm Hg ↑ PCO2 per 1 mEq/L ↑ in [HCO3−]
* 5 mEq/L ↓ [HCO3−] per 10 mm Hg ↓ in PCO2

Treat the patient not the ABG!!!

Thank you…