

Acid base balance

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Acid base balance

Definition of PH (7.36-7.44) ^{→ power of H^+} [-ve log of H^+ concentration to the base 10]...

Acidosis $pH < 7.3$

Alkalosis $pH > 7.4$

Buffer systems: Is a weak acid or base and salt of that acid or base...



Main extracellular buffer is Bicarbonate 65%. ^{presented in the plasma...} [the plasma protein - phosphate help it]...

Main intracellular buffer is Proteins 30% Bone, and Phosphate

^{↳ not true Buffer}
[K^+ or Na^+ will be released from Bone, to help H^+]

Acid base balance

Acids

Are molecules that have the ability to ^{or give} Release H^+ ions

Fixed acids [strong] ^{متكاثرة} Volatile acids [weak].

↳ as sulfate - phosphate -

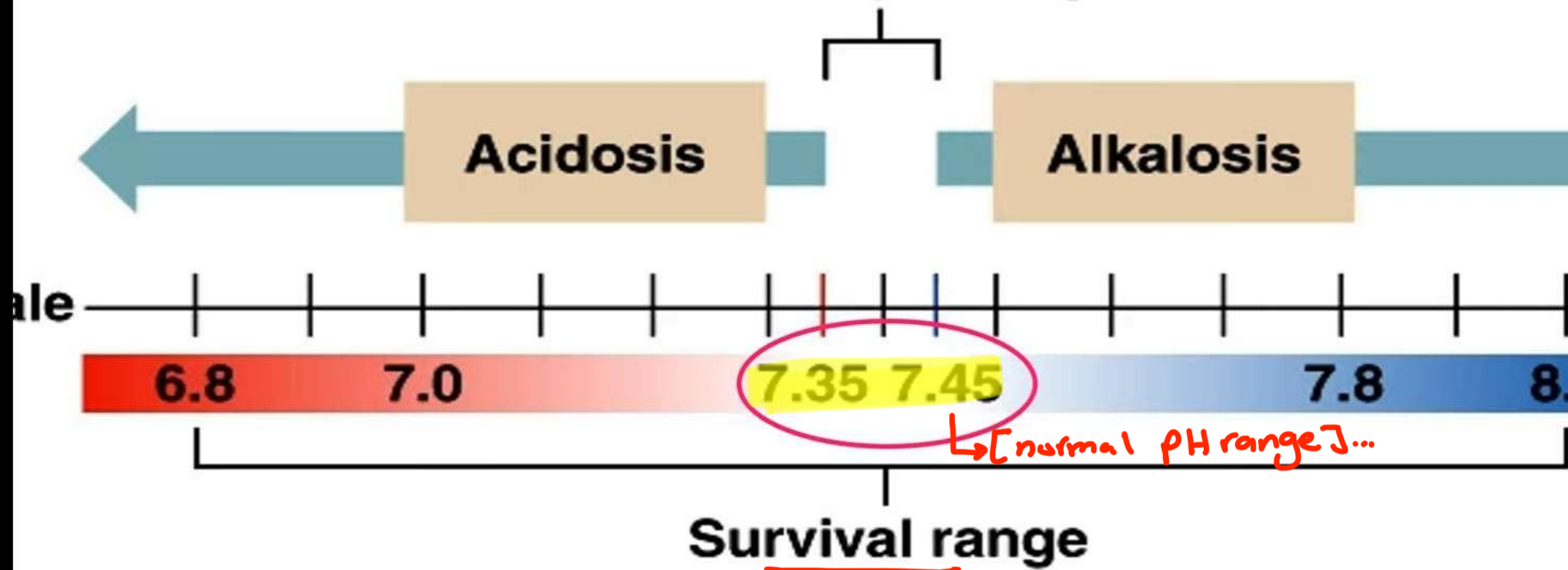
↳ as: carbonic acid [may become to $CO_2 - H_2O$ متطايرة]...

Bases lactate - Hydrochloric acids

Are molecules that have the ability to accept or Bind with H^+ ions.

pH of arterial blood

Normal pH range



BICARBONATE BUFFER SYSTEM



[shift to the l_f in Acidosis]
to washout the CO₂ in exp. air

Addition of lactic acid

Exercise

↳ ↑ lactic acid from sweating.

Vomiting

Loss of HCl

[shift to the R_t in the Alkalosis]

حتى يعود ضغط الدم إلى طبيعته
NG tube or vomiting
to degenerate H⁺

Continue



Lung control CO_2 level via shifting the equation to the R $[\text{H}_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O}]$
exp. air ﴿ بيطلع خالص ﴾

Kidney control HCO_3 level through. :-

① ♦ Reabsorption of HCO_3 Proximal renal tubules . ﴿ 85% of HCO_3 control ﴾

② ♦ Generation of HCO_3 Distal renal tubules . ﴿ 15% of HCO_3 control ﴾...

How does lung control CO_2 level?

Shifting the equation to left . $H_2CO_3 \rightarrow CO_2 + H_2O$

[The Acidosis $\rightarrow \uparrow H^+$ which stimulate the chemoreceptors in Carotid body in Carotid bifurcation or in the Brain stem medulla $\rightarrow$ lead to $\uparrow$ rate and depth of breathing]...

Medullary , Carotid body Chemoreceptors stimulate
rate of respiration . [Alkalosis $\rightarrow$ $\downarrow$ rate of breathing]...

CO_2 diffuse 20 times faster than O_2 .

$\hookrightarrow$ faster changes

Acid base regulation

Maintenance of acceptable range of PH in ECF is accomplished by Three mechanisms. ↗ 7.35 - 7.45

① Chemical buffers ↗ intra cellular [protein - sulfate] -
↘ extra cellular [carbonate - Hb - plasma protein]...

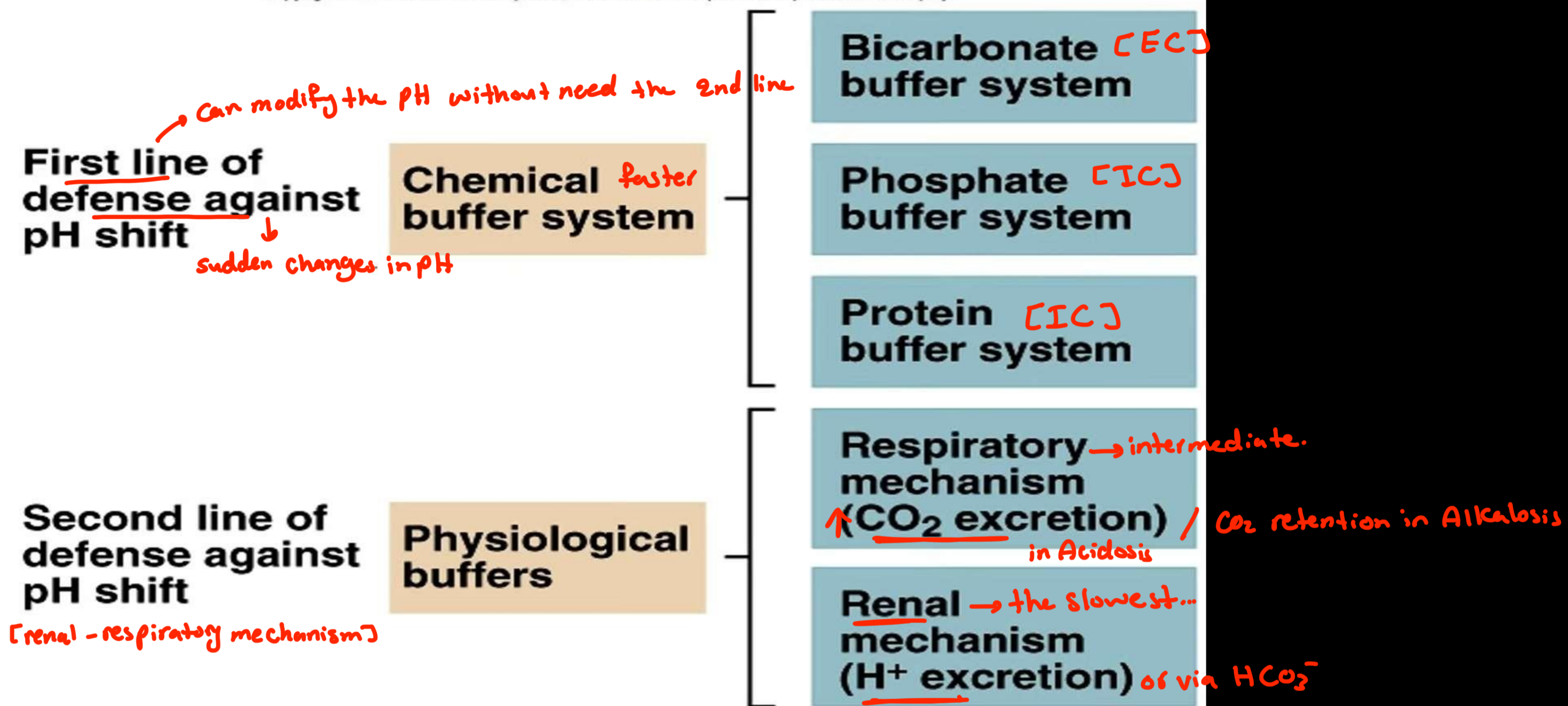
React Very Rapidly Seconds to minutes.

② Respiratory regulations ↗ as ↑ rate of Breathing in shock... [occur via the lungs]...

Reacts Rapidly ↗ intermediate. minutes to hours .

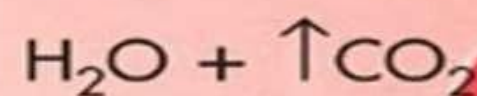
③ Renal regulations ↗ via HCO_3^-

Reacts Slowly Hours to days.

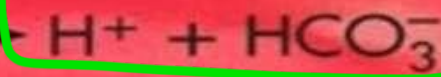
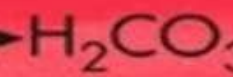


Circulation

Erythrocyte



Carbonic
anhydrase



[Hb] → there is histidine
may bind to H^+ ...

Lungs

Respiratory
center in
brain stem

↑Respiration rate
and depth

in Acidosis

↑ CO_2 given off

← عبر التنفس، CO_2 زائد
or ↑ CO_2 [CO_2 retention]...

in Acidosis ↑Rate - depth of breathing

↳ Kussmaul breathing...

دریسکی صبحی، Alkalosis

Kidney

↳ ↑ rate of H^+ excretion
or HCO_3^- excretion
or retention...

↓pH

↑Rate of H^+ secretion

In Acidosis the urine become acidic... دریسکی صبحی

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

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Acidosis/alkalosis

■ PH changes has dramatic effects on cell functions.

→ in Acidosis the excitability decreased...
→ in Alkalosis the excitability increased...

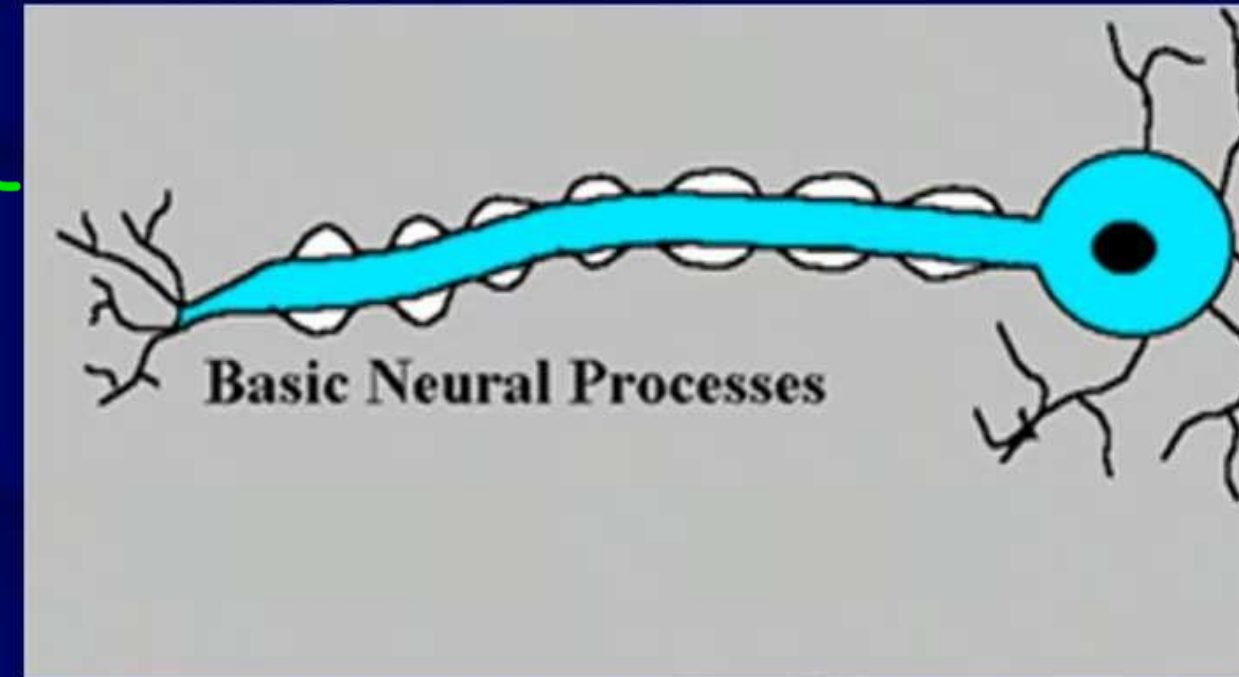
■ Change in excitability of nerve and muscle cell.

■ Influence enzyme activity. in Acidosis the enzyme activity decreased → دیکھی صحیح ہے Alkalosis ال

■ Influence K^+ levels.

← Acidosis H^+ ↑ مزاج یہ دل اور H^+ جواں ر
cells to ↓ the acidosis and excrete K^+
from IC → EC...

especially the
coagulating
enzyme...



* In trauma and shock there is lethal triad:-
1- acidosis 2- Coagulopathy 3- Hypothermia...

**Accumulation
of acids** acidosis

↳ in Renal Failure - DKA -
Cardiogenic shock - Bleeding

**Loss of
bases** Acidosis

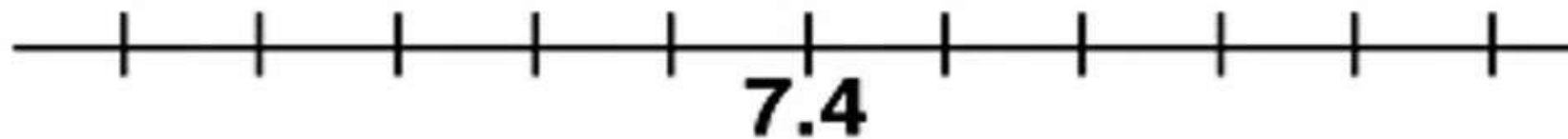
↳ in diarrhea...

Increased concentration of H^+

Acidosis ✓

pH drops

pH scale



pH rises

Alkalosis ✓

Decreased concentration of H^+

↳ in vomiting - NG tube loss

**Loss of
acids**

↳ in $NaHCO_3$ replacement

**Accumulation
of bases**

Henderson-Hasselbach equation

Body $pH = pK + \log \frac{\text{B} \overset{\text{in plasma}}{\text{HCO}_3}}{\text{H}_2\text{CO}_3} = \frac{24 \text{ mEq/L}}{1.2 \text{ mEq/L}} = \frac{20}{1} = 7.4$

$\hookrightarrow p_{\text{CO}_2} \times \alpha_{\text{CO}_2} = 0.03 \times 40 = 1.2 \dots$

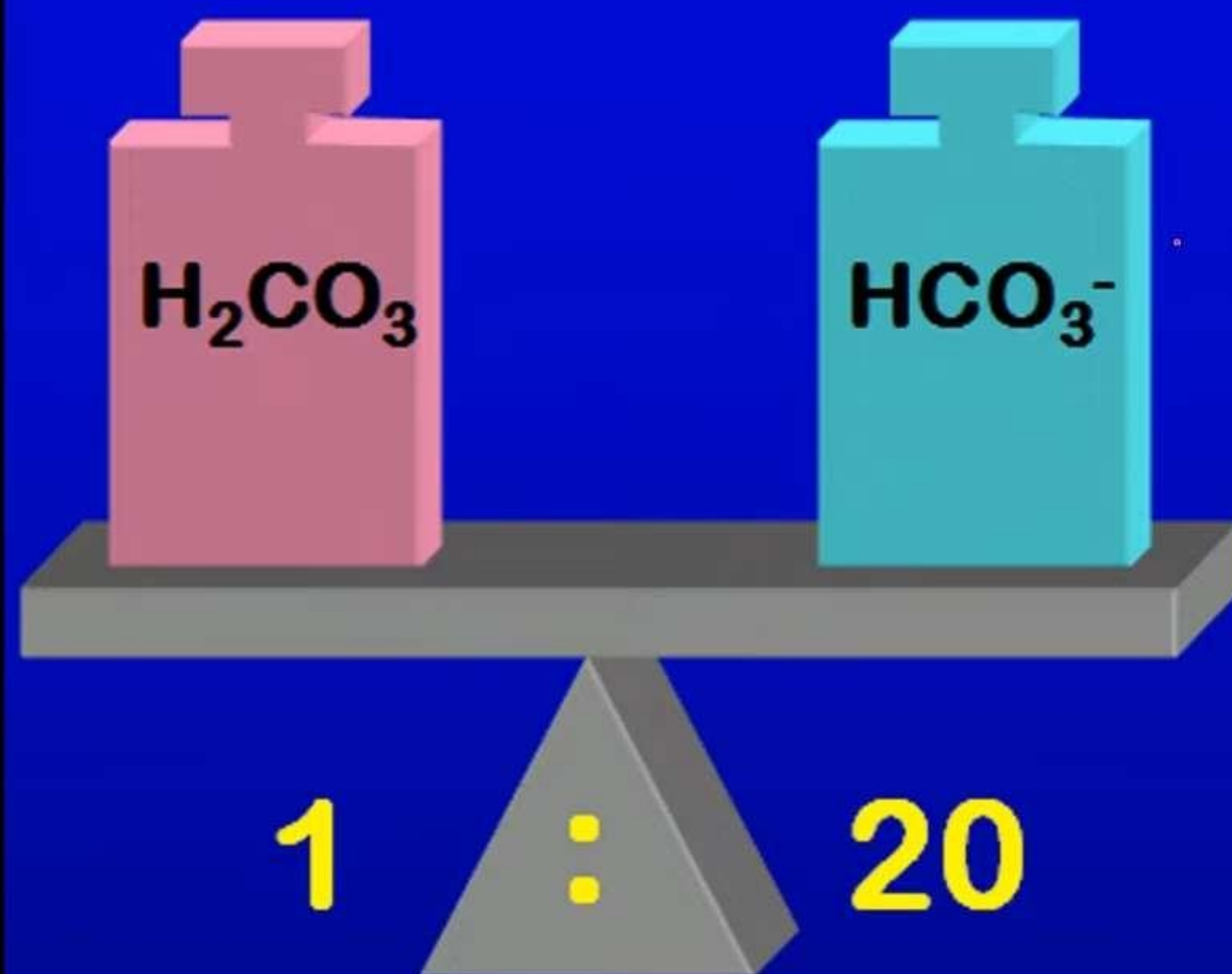
المرم بالنسبة تطلع النسبة 20:1
لغرض النظر عن قيم الـ H_2CO_3 - BHCO_3

The pH is Dictated by Ratio of HCO_3 to CO_2 .

If ratio is 20 :1 PH is 7.4. normally

Increase HCO_3 increase CO_2 to keep ratio constant. رافض صريح

* In Acidosis there is $\downarrow \text{HCO}_3^-$ so the H_2CO_3 decreased [compensatory mechanism]
to mantiane the body pH $\rightarrow \frac{20}{1} = 7.4$ [Alkalosis رافض صريح]...



H_2CO_3 : Carbonic Acid

HCO_3^- : Bicarbonate Ion

$(\text{Na}^+) \text{HCO}_3^-$

$(\text{K}^+) \text{HCO}_3^-$

$(\text{Mg}^{++}) \text{HCO}_3^-$

$(\text{Ca}^{++}) \text{HCO}_3^-$

-metabolic balance before onset of acidosis

-pH 7.4

Respiratory Control Mechanisms:

in Alkalosis lead to ↓ rate and depth of breathing...
in Acidosis lead to ↑ rate and depth of breathing...

Works Within Minutes to control pH : maximal in 12-24 hours.

Only about 50-75% effective in returning pH to normal.

Excess CO_2 & H^+ in the blood act directly on respiratory centers in the brain, carotid body . [act on chemo receptors]

CO_2 readily crosses blood-brain barrier reacting w/ H_2O to form H_2CO_3 .

H_2CO_3 splits into H^+ & HCO_3^- & the H^+ stimulates an increased or decrease in respirations.

Renal control mechanisms

^[weaker]
Don't work as fast as respiratory mechanisms, functions for Days to restore PH to normal level.

Regulate PH through exerting ^{→ in acidosis} Acidic or ^{→ in alkalosis} Alkaline urine, excreting excess H^+ , and Regeneration and Reabsorption of HCO_3 .

Excreting acidic urine decrease acidity of EC fluid,
excreting alkaline urine remove base ^{→ in the metabolic alkalosis case...}



Normal Arterial Blood Gas (ABG) Lab Values:

From Radial or Femoral Artery...

□ Arterial pH: 7.35 – 7.45 [7.4] ✓

□ HCO_3^- : 22 – 26 mEq/L [24] ✓

□ PaCO_2 : 35 – 45 mmHg [40] ✓

□ TCO_2 : 23 – 27 mmol/L

□ PaO_2 : 80 – 100 mmHg * PaO_2

in venous Blood:- 75 mmHg...

in arterial Blood:- 95 - 100 mmHg...

Saturation of O_2 ←

□ SaO_2 : 95% or greater (pulse ox) → if it < 90% suddenly the PaO_2 will decrease کبیر...

Base deficit ← □ Base Excess: -2 to +2 [±3] ✓

□ Anion Gap: 7 – 14 [8-12] ✓

ACIDOSIS / ALKALOSIS

Acidosis and Alkalosis are categorized as Metabolic or respiratory depending on their Primary Cause.

■ Metabolic Acidosis and Metabolic Alkalosis

Caused by an imbalance in the production and excretion of Acids or Bases by the Kidneys. $[HCO_3^-]$

■ Respiratory Acidosis and Respiratory Alkalosis

Caused primarily by Lung or breathing disorders.

* pt can't breathe $\rightarrow \uparrow CO_2$ [resp. acidosis]... * $\uparrow$ Breathing $\rightarrow$ washing out the $CO_2 \rightarrow \downarrow CO_2 \rightarrow$ resp. Alkalosis...

due to emphysema - asthma -
rib fracture ..etc

NB : 90% of ICU patients has Acid base disturbance

$\hookrightarrow$ wide common in ICU pt...

Disorders of Acid-Base Metabolism

Is due to ^{lack} lack of balance between rate

① Production of acid and base . *what ever the cause...*

② Body ability to compensate. *[lung - kidney defense] ...*

E: Rapid rate of production of acid or base , or defect ^{DKA - lactic acidosis...} physiological compensatory mechanisms.

↳ shock + emphysema

* Pt has massive Bleeding → shock → ↓ pH , ↓ HCO_3^- [metabolic acidosis]...

* NaHCO_3 intake lead to Alkalosis → ↑ pH , ↑ HCO_3^- [metabolic Alkalosis]...

↳ used for ulcers

Metabolic acidosis most import in surgery...

↳ 50% due to lactic acidosis [shock] → mcc ...

uses

① Increase acid production

endogenous acids

mc in surgical pt
surgical topic ← Shock (lactic acid). due to hemorrhage or RTA or sepsis [any type of shock]...

IM topic ← Diabetes (keto acids). as DKA..
[Renal failure (Sulfuric, Phosphoric acid) . ✓]

exogenous acids in poisoning...

Methanol, Ethyl alcohol.

② Increase alkali excretion (GIT-Kidney)

Diarrhea, small bowel, pancreatic fistula.

Uretro – sigmoidostomy.

Renal tubular acidosis .

What is the most common cause M A in surgical patients?

- ^{50% of metabolic acidosis...} Shock & Sepsis → Decrease tissue perfusion →
Lactic Acidosis → Anaerobic metabolism →
wide anion gap. ✓
- Severe anemia.
- Severe hypoxemia.

What is anion gap (AG) — unmeasured acids...

↳ wide - narrow...

Definition

AG is the Difference between measured Cations and measured Anions. $\left\langle \begin{matrix} \text{Na}^+ \\ \text{K}^+ \end{matrix} \right\rangle \left\langle \begin{matrix} \text{Cl}^- \\ \text{HCO}_3^- \end{matrix} \right\rangle$

$$\text{AG} = \text{Na} - (\text{Cl}^- + \text{HCO}_3^-) = 8 \pm 4 \text{ MEQ / L}$$

140 - [105 + 24] = 8 - 12 ..

Increase acid production increase AG. >12 [wide]

↓ HCO₃⁻ - ↑ Cl⁻ so the gap is normal... ← Increase alkali loss normal AG.

NB : Hypo albuminemia ^{as an acid} Reduce AG <8 [narrow]

in ICU p⁺ ← Each 1 gm decrease albumin decrease gap by 2.5.

* in wide gap → ↓ HCO₃⁻ [↑ unmeasured acids]..

	Cl ⁻
Na ⁺	
	HCO ₃ ⁻
	AG

* normal albumin :- 4.5
if there is hypo albuminemia
[albumin = 2.5]
يعني انخفض بـ 2gm
so the gap = 2 x 2.5
= 5 gap , مقدار انخفاض

unmeasured acids [phosphoric acid - sulfuric acid - lactic acid]
↓
50% of the metabolic acidosis

↳ Albumin ↓

Anion gap metabolic acidosis

[wide gap causes] :-

[MUD Pile] اسباب

- **Methanol** poisoning...

- **Uremia** ✓

- **Diabetic ketoacidosis** ✓

- **Propylene glycol**

- **Isoniazid** used in TB...

- **Lactic acid** ✓

- **Ethylene glycol**

- **Rhabdomyolysis**

- **Salicylates** intoxication
↳ Aspirin toxicity...

Non anion gap metabolic acidosis

↳ normal [loss of AlKali]

[FUSED CARS]

الحموضة / لا سبب

Fistula (pancreatic). ✓

Uretro - enterostomy.

↑ **Saline administration.** ✓ ✍

Endocrine (hyperparathyroidism).

Diarrhea. ✓

Carbonic anhydrase inhibitors.

Ammonium chloride

Renal tubular acidosis

Spiroinolactone

Symptoms of Acidosis...

Lethargy ✓, headache. ✓

[↓ HCO_3^- → wash out the CO_2]... Deep rapid breathing Kussmaul's breathing. ✓

Cardiac arrhythmias, Decrease CO. [weak heart contractility]

Depression of CNS, Coma. [worsen the problem...]
[fetus]...

Treatment

Treat the Cause. ✓

In severe cases give NaHCO_3 . → we give it for life saving [not routinely used]

pH less than 7.2 ✓

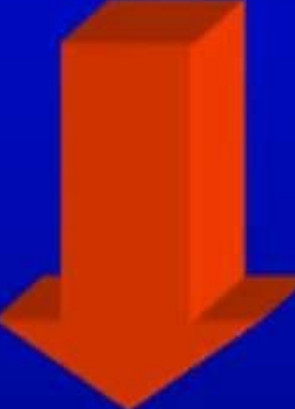
HCO_3 less than 12 ✓

} start to affect the heart contractility...

EFFECTS OF pH

♥ The most general effect of pH changes are on enzyme function

♠ Also affect excitability of nerve and muscle cells

 **pH**  **Excitability**
[acidosis] *↓ of muscle and nerve cells...*

 **pH**  **Excitability**
[Alkalosis]

0.3X Wt x Base Deficit → normal HCO_3^- - measured plasma HCO_3^-
24 - 14 [for ex] = 10

$$0.3 \times 70 \times 10 = 210 \text{mEq/l NaHCO}_3$$

Give half over 20 minute, rest over 4 h → HCO_3^-
موتن نخل ال heart يستغل

8.4 % NaHCO_3 1ml = 1mmol

4.2 % NaHCO_3 1ml = 1/2 mmol

0.6 x Wt x (15 - plasma HCO_3^-) → used in severe metabolic acidosis
طريقة جديدة
منه صرخا زيج ال HCO_3^- normal level

But we give the pt dose of HCO_3^-
to overcome the severe metabolic
acidosis...

What is compensated MA → ↑ Breathing

- Look for paco₂ → expected pco₂ → < 40

$$\boxed{1.5 \times HCO_3 + 8} \quad \text{for example} = 1.5 \times 15 + 8 = \underline{\underline{27}} \text{ } \text{paco}_2 \text{ } \text{منخفض}$$

Yes ^{resp.} compensated MA. ✓

No added Respiratory Acidosis.

له صفا قادر يتنفس

Metabolic alkalosis

→ mainly medical topic except the vomiting → surgical
↳ mainly due to pyloric obst. in surgery...

■ Loss of acid from GIT, or Kidney
(Vomiting, Over diuresis, Ascites) ^{or NG tube loss}

Chloride Sensitive ✓

■ Diuretic therapy

■ Excessive alkali Administration

■ Massive blood transfusion

■ Severe K depletion

■ Mineralocorticoid excess

↳ ↑ Aldosterone

Chloride Resistance ✓

* 1L normal saline has :- 154 mmol of Na^+ and 154 mmol of Cl^-

↳ less than 25
↓ urine acidity ← ↓ HCl
called Cl^- sensitive
normal saline improves
Saline...

we find urine acid
more than 25...
[Cl^- resistance]..
↳ not respond to
normal saline but
improved when we treat
the cause..

Patient with alkalosis is always K Deficit

reabsorption by the kidney

K move into cell [So in Alkalosis always there is Hypokalemia]...

K is lost in urine

H⁺ move to ECV

↳ excreted by the kidney...

So always give potassium

Urine should be adequate first.

Symptoms of Alkalosis [metabolic]

↳ symptom of $\downarrow K^+$ - $\downarrow$ phosphate - $\downarrow Ca^{++}$ in blood

^{due to $\downarrow Ca^{++}$}
Increase neuromuscular excitability, parathesia.

Carmo - pedal spasm.

Keynes-stokes breathing with period of apnea 5-30 s

Arrhythmias.

Muscle weakness paralytic ileuss. ^{due to $\downarrow K^+$}

Decrease cerebral blood flow confusion.

ما بقہ - یتغنی علی عکس د
Acidosis کا - rapid - deep breathing...

What is paradoxical aciduria ?

~~↳ if there is Alkalosis with acidic urine...~~

Early in pyloric obstruction patient is loosing acid,
kidney excrete HCO_3 , so urine is alkaline. *in early stage.*
[vomiting]
lead to metabolic alkalosis

Later, volume depletion, Hypokalemia, lead
زيادة حجم السوائل
increase K Reabsorption and H secretion
[In neglected pt]
leading to paradoxical aciduria .
indicate late stage of pyloric stenosis [vomiting]..

Treatment of metabolic alkalosis

Most of alkalosis is Volume Responsive. due to vomiting $\downarrow$ HCl

Treatment by volume expansion by NaCl $\rightarrow$ Cl^- sensitive...

Add KCL

PaCO_2 in metabolic alkalosis is $0.7 \times \text{HCO}_3^- + 40$

لے کہ ارتقاہ ۱ معیار HCO_3^- راجع بقا بہا ارتقاہ ۰.۷ معیار PaCO_2 ...

Respiratory acidosis

↳ the pt unable to breathe [$\uparrow$ p_{aCO_2} - $\downarrow$ pH]

Retention of CO₂ ↓ (alveolar ventilation).

air way obstruction, pneumonia, pleural effusion, fracture ribs,
asthma.

Depression of respiratory center (Morphine -CNS injury)

Upper abdominal incisions. post op + anesthesia obstructs

Tense ascites, distension.

Large PE, fever. ↳ the diaphragm can't move down → $\uparrow$ CO₂...

Myopathy.

Symptoms of respiratory acidosis?

CO₂ NARCOSIS → $CO_2 > 65 - 70 \text{ mmHg}$...

- Headache , blurred vision.
- Anxiety , restless , tremors.
- Coma.

RESPIRATORY ACIDOSIS

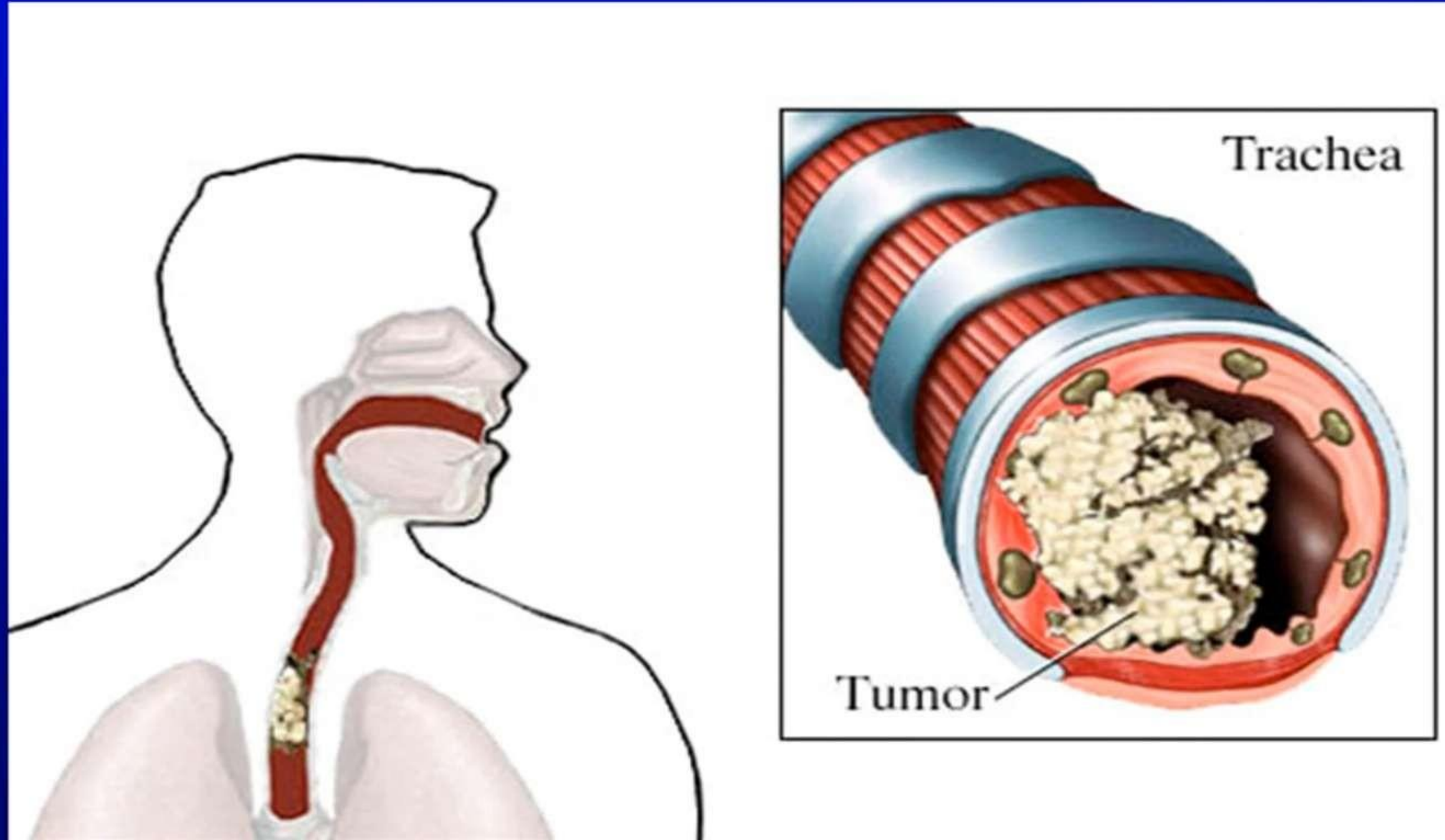
• Decreased CO_2 removal can be the result of:

- 1) Obstruction of air passages
- 2) Decreased respiration (depression of respiratory centers)
- 3) Decreased gas exchange between pulmonary capillaries and air sacs of lungs
- 4) Collapse of lung



RESPIRATORY ACIDOSIS

- ♥ ①) Obstruction of air passages ^{→ CO₂ retention-} ^{due to aspiration - edema -}
♠ Vomit, anaphylaxis, tracheal cancer



RESPIRATORY ACIDOSIS

♥ 2) Decreased Respiration → ↑CO₂

♠ Shallow, slow breathing [every 4-5 sec take one breath]...

♠ Depression of the respiratory centers in the brain which control breathing rates

♦ Drug overdose inhibit the resp. center.



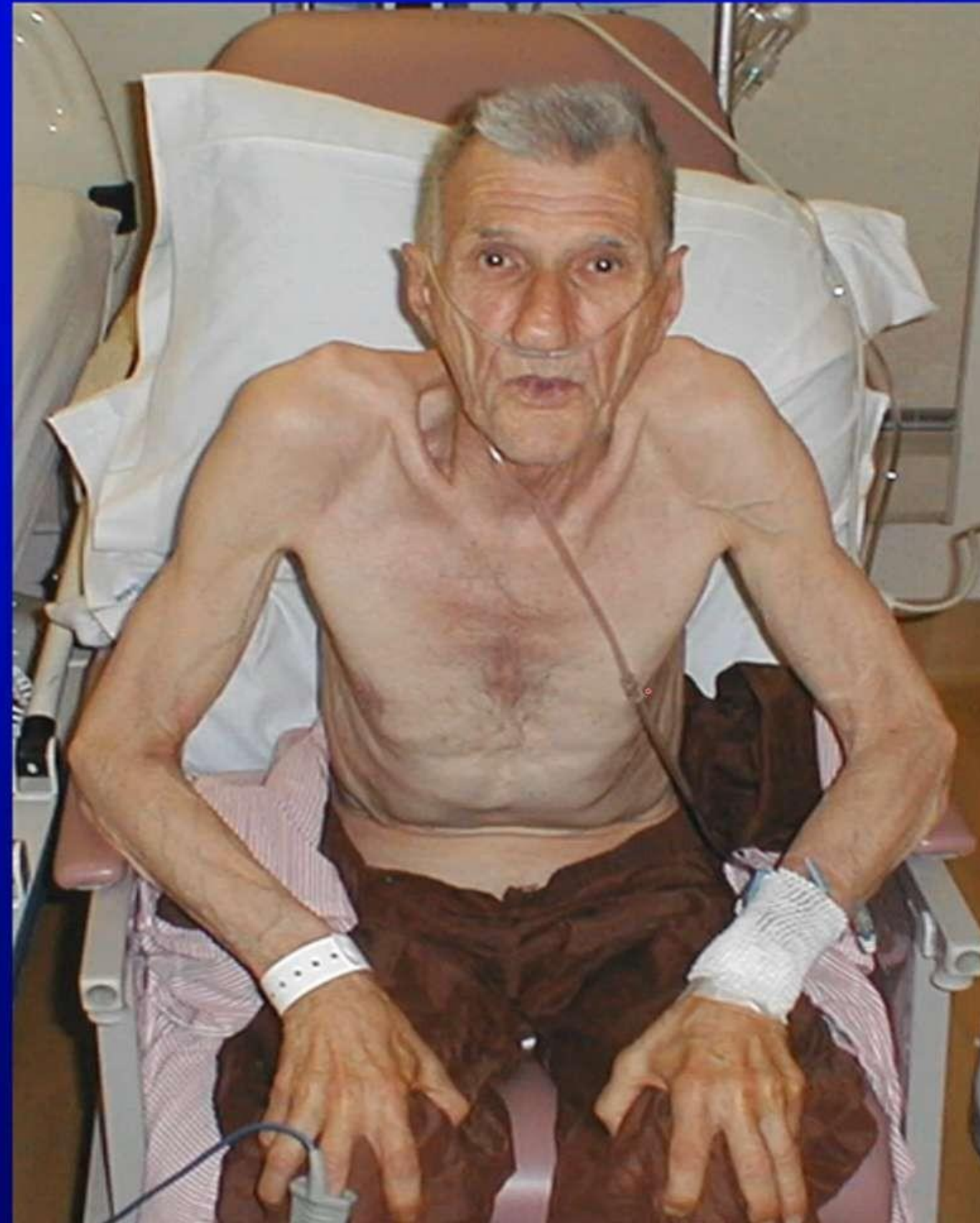
RESPIRATORY ACIDOSIS

♥ 3) Decreased
gas exchange
between
pulmonary
capillaries and
air sacs of lungs

♠ Emphysema ✓

♠ Bronchitis ✓

♠ Pulmonary
edema ✓



RESPIRATORY ACIDOSIS

♥ 4) Collapse of lung [massive hemothorax]

♠ Compression injury, open thoracic wound

Left lung
collapsed



← مريضاً اعطينا muscle relaxant + anesthesia ورضنا مريضاً بمرحلة قبل ما نطلع كل ال muscle relaxant من الجسم ← يعني حتى راح يقدر يتنفس فيه
في resp. muscle relaxation ← $\uparrow$ CO₂ retention ← resp. acidosis ← May lead to death ...

← راضاً عنده upper abdominal incision فحتى قادر يتنفس من المربع راح به فل ب respiratory acidosis ...

← مريضاً عنده بلغم بمره وحته قادر يطلع من المربع راح يعمل airway obst. بس ال mucus plaque ← lead to CO₂ accumulation
↳ resp. acidosis

فحتى نخرج طبيعه لمره حتى نطلع البلغم + حتى يقدر يتنفس
* Post op. Care:- we should give the pt should analgesia
+ نتأكد انه ما بفرح بمره قبل ما نطلع كل ال muscle relaxant from the Body ...

Respiratory alkalosis

Hyperventilation rapid Breath to wash out the CO₂

- Fever, pain, sepsis. [gram -ve]
- Assisted ventilation.
- Head injury.
- Respiratory center lesion stroke, tumor
- Hysterical. mc in ER
- Salicylate poisoning.
- Hypoxia, hypotension high altitude.
- Pulmonary embolism.
 → if it small lead to resp. Alkalosis...
 → if it large lead to resp. acidosis...

psychological trauma ←