Atahotel Executive, Milano 2012
VI CONGRESSO NAZIONALE DI ECOCARDIOCHIRURGIA

Interpretare "al volo" una emogasanalisi…

D. PENZO

SC di Anestesia e Rianimazione 2

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pH

**pondus hydrogenii*

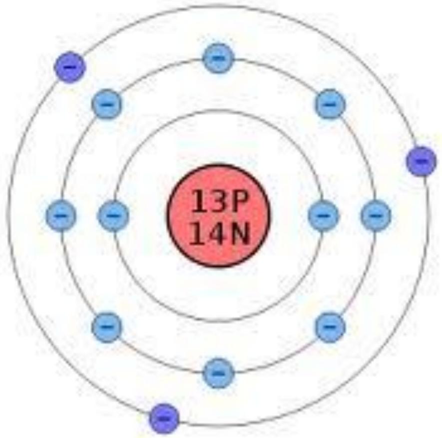
table 2.5 Hydrogen Ion Concentrations and pH

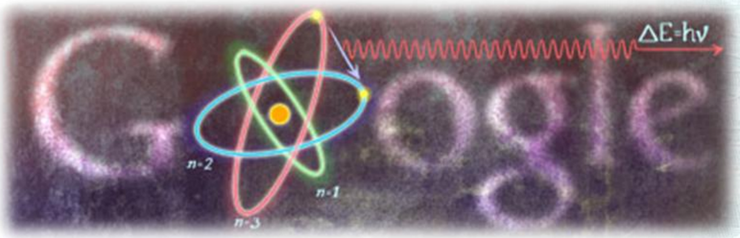
Grams of H^+ per Liter	pH	
0.00000000000001	14	↑
0.0000000000001	13	
0.000000000001	12	Increasingly basic
0.00000000001	11	
0.0000000001	10	
0.000000001	9	
0.00000001	8	
0.0000001	7	Neutral—neither acidic nor basic
0.000001	6	
0.00001	5	
0.0001	4	
0.001	3	Increasingly acidic
0.01	2	
0.1	1	
1.0	0	↓

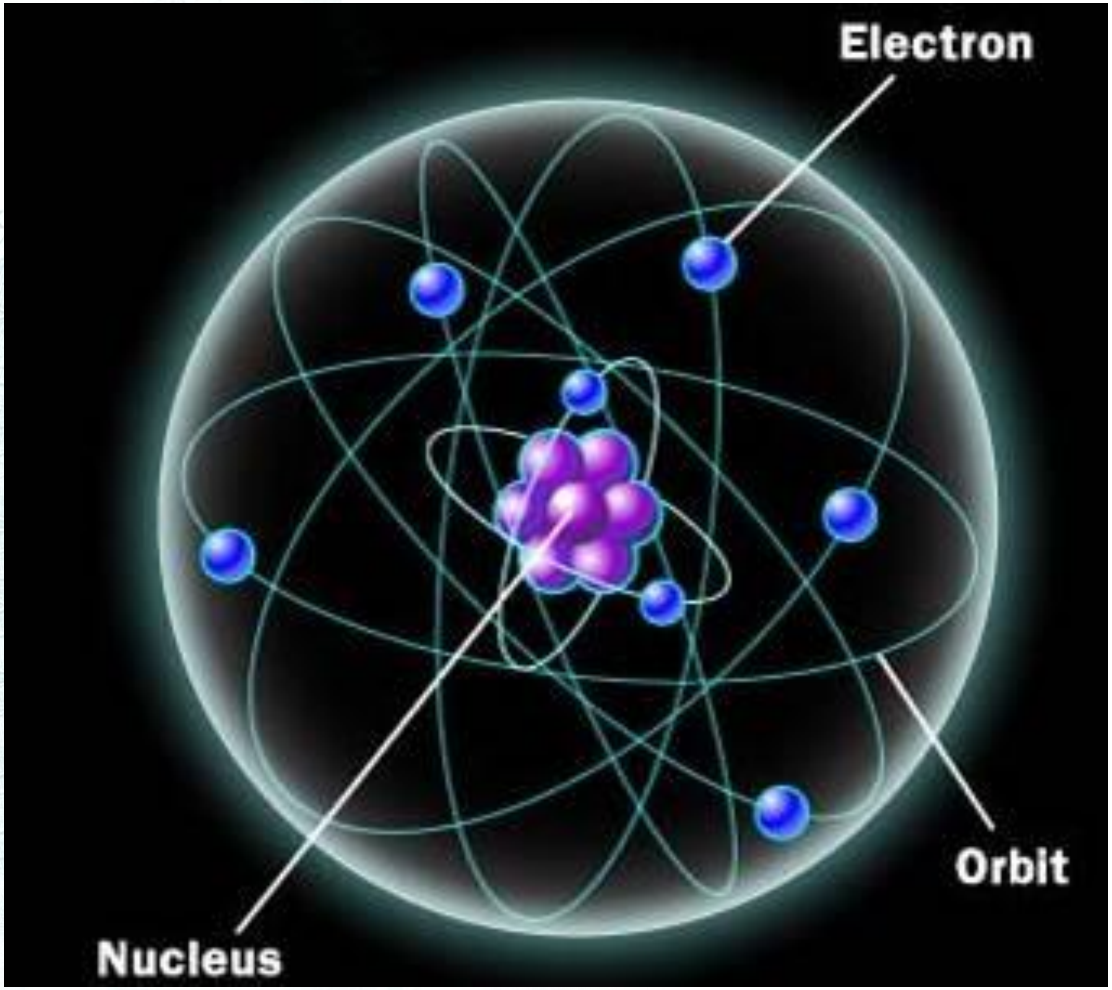
- Normal concentration of H^+ in body fluid is 4×10^{-8} mol/L.
- pH=- log $[H^+]$
- Range of pH is from 0 - 14
- Normal pH of blood is 7.35-7.45

Søren Sørensen. Courtesy Oesper Collection, University of Cincinnati.

...introduced in 1909 by the Danish chemist ***Søren Sørensen (1868–1939)*** *as a convenient way of expressing acidity..*

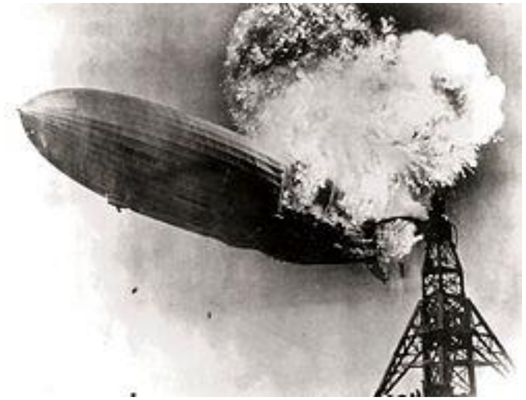


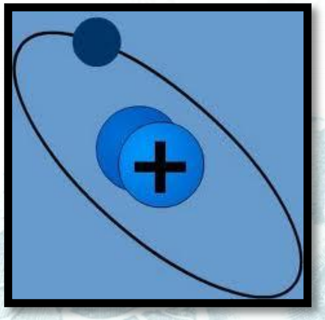




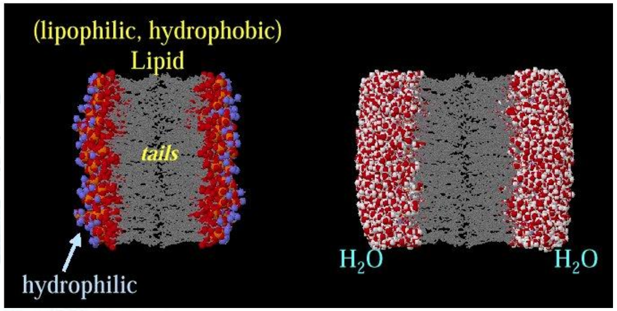
[H+] = 35-45 nanomoli/L

REATTIVITA' BIOLOGICA MOLTO ELEVATA

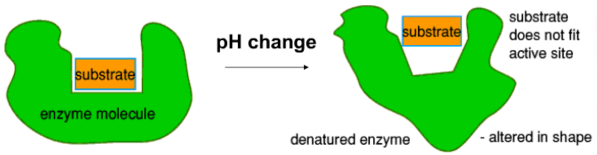




H^+



variazioni delle configurazioni steriche di proteine ed enzimi

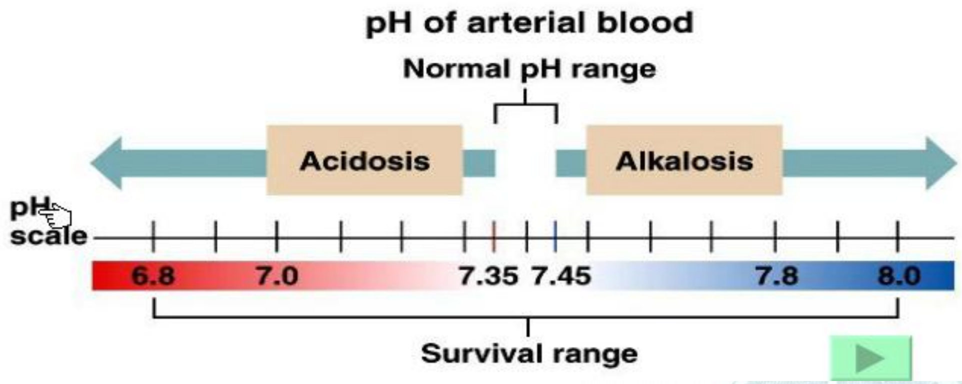


Alteration of enzymatic activity

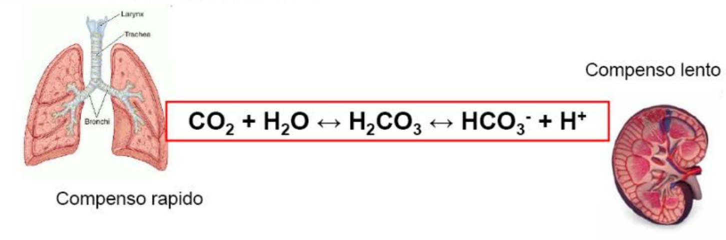
- pH change out of normal range can alter the shape of the enzyme rendering it non-functional

Alterazioni strutturali

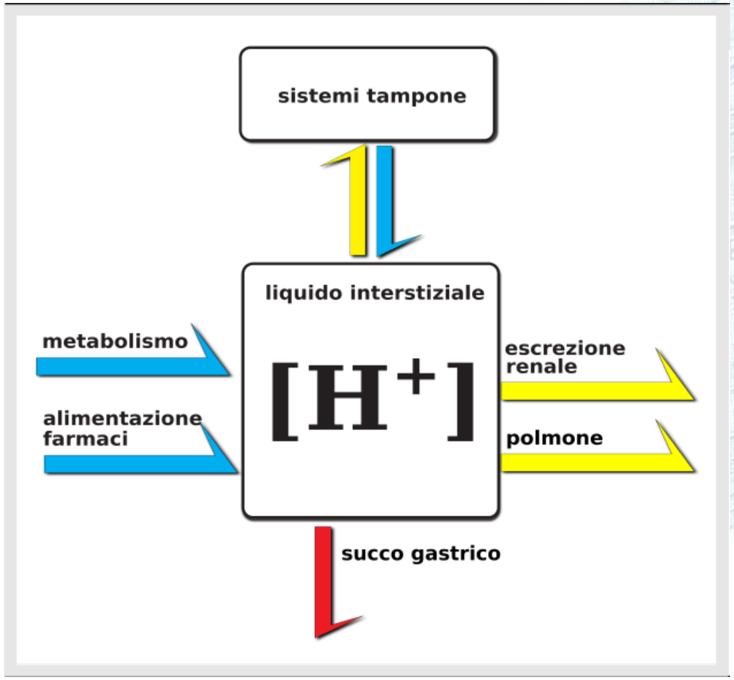
Alterazioni funzionali



Equilibrio Acido-base



- …*insieme dei processi fisiologici* ***che agendo sinergicamente, concorrono a mantenere un livello di acidità (e quindi di pH) STABILE e COMPATIBILE con lo svolgimento delle principali funzioni metaboliche***



- Tamponi intra- extracellulari
- Controllo della pCO2, tramite variazione della **Va**
- Controllo della concentrazione di HCO3- attraverso la variazione dell' escrezione renale di H+

Sistema Tampone al Bicarbonato

(H2CO3+Na HCO3)

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

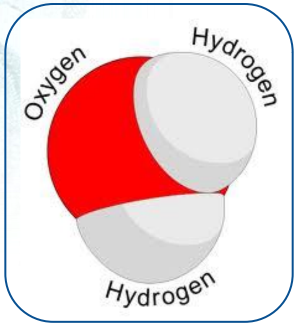
HCl ***+ Na HCO3*** $\longrightarrow$ ***H2CO3 + NaCl***

SOL.TAMPONE: Soluzioni costituite da un ACIDO (O BASE) DEBOLE in parte SALIFICATO con una BASE (O ACIDO) FORTE: la loro funzione è quella di attenuare (tamponare) le variazioni di pH che altrimenti si verificherebbero in seguito a piccole aggiunte di un Acido o di una Base.

$\_COOH \longrightarrow \_COO^- + H^+$

$\_NH_3OH \longrightarrow \_NH_3^+ + OH^- \longrightarrow H^+ \;\}\; H_2O$

(radicali basici liberi dei tamponi proteici)



Un sistema tampone è costituito da un acido e dalla sua base coniugata ed è in grado di rilasciare o legare H+ a seconda delle necessità. In caso di legame → l'H+ cessa temporaneamente di esistere come specie dissociata autonoma (e quindi altamente reattiva) nel fluido contenente il tampone

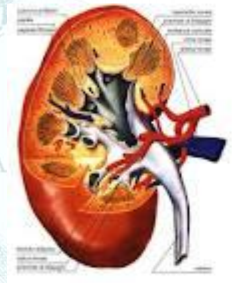
Buffers in the human body

Buffer	Acid	Conjugate base	Main buffering action
hemoglobin	HHb	Hb^-	erythrocytes
proteins	HProt	$Prot^-$	intracellular
phosphate buffer	$H_2PO_4^-$	HPO_4^{2-}	intracellular
bicarbonate	$CO_2 \rightarrow H_2CO_3$	HCO_3^-	extracellular

Tamponi cellulari

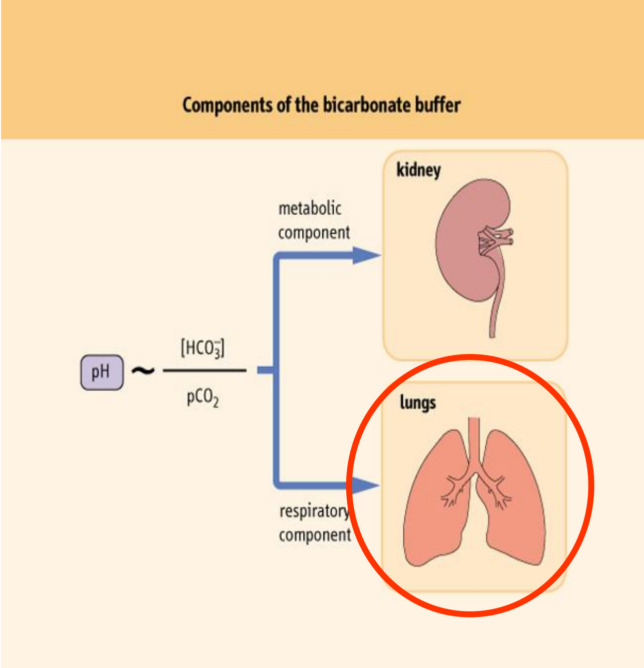
$\downarrow\uparrow$

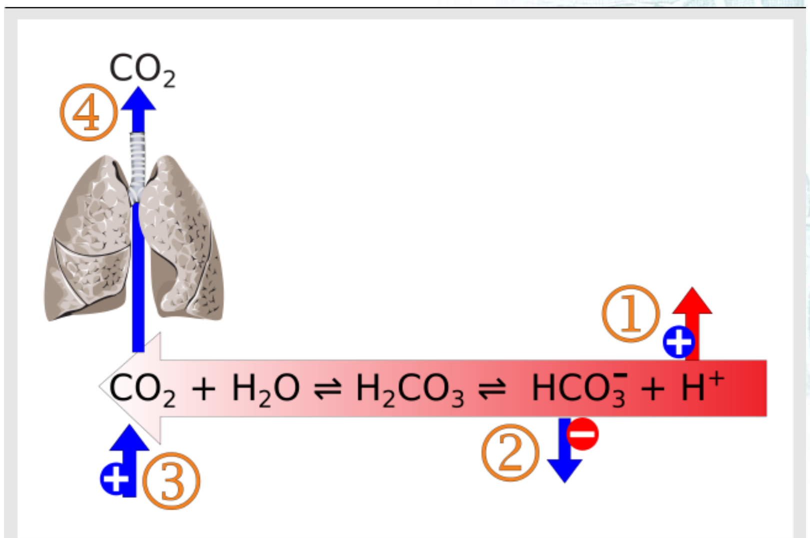
$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

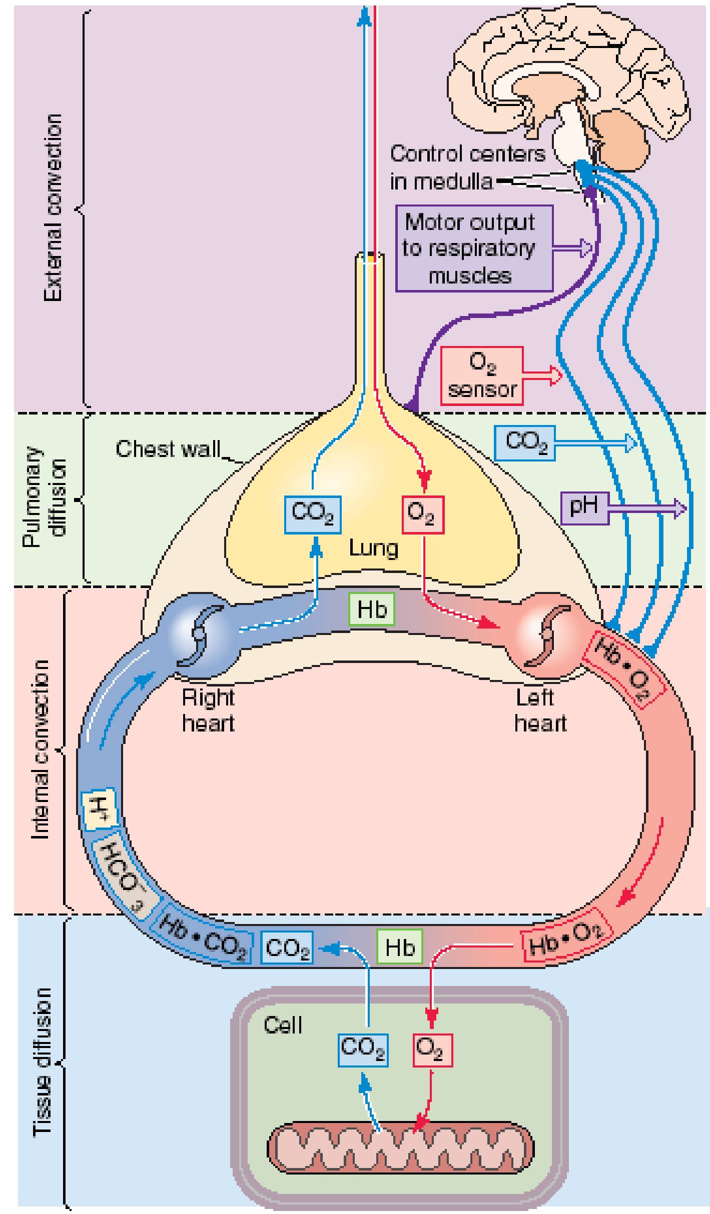


L'equilibrio di dissociazione del sistema tampone $HCO3/H_2CO_3$ è descritto dalla legge d'azione di massa, espressa come equazione di ***<u>Henderson-Hasselbach</u>****, nella quale l'H_2CO_3 è inserito sotto forma di PaCO2 moltiplicata per un coefficiente di solubilità della CO_2 in H_2O (si ottiene un dato in mEq/L)*

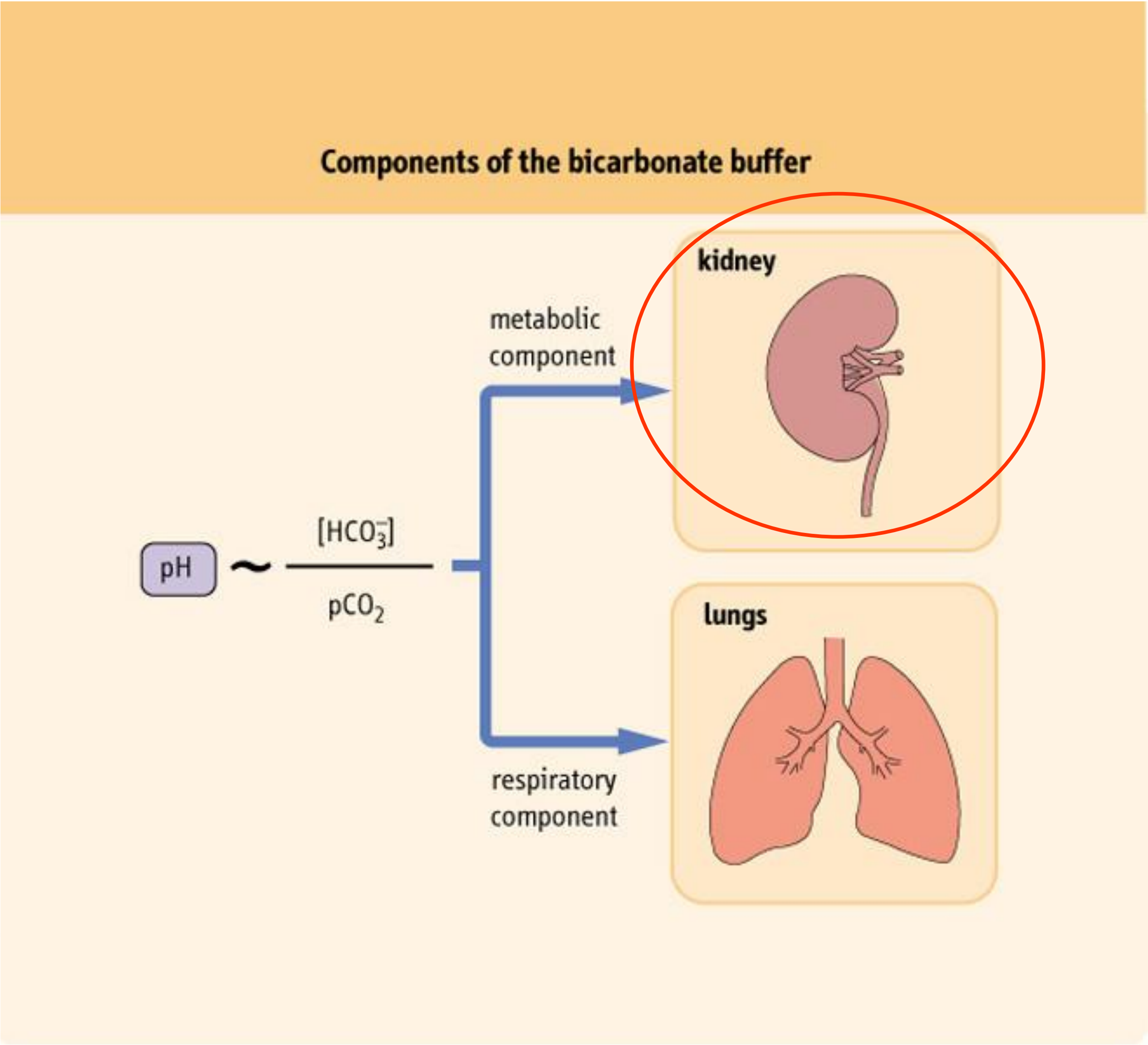
$$pH = 6.1 + \log \frac{HCO3^-}{0.0301 \times PaCO_2}$$

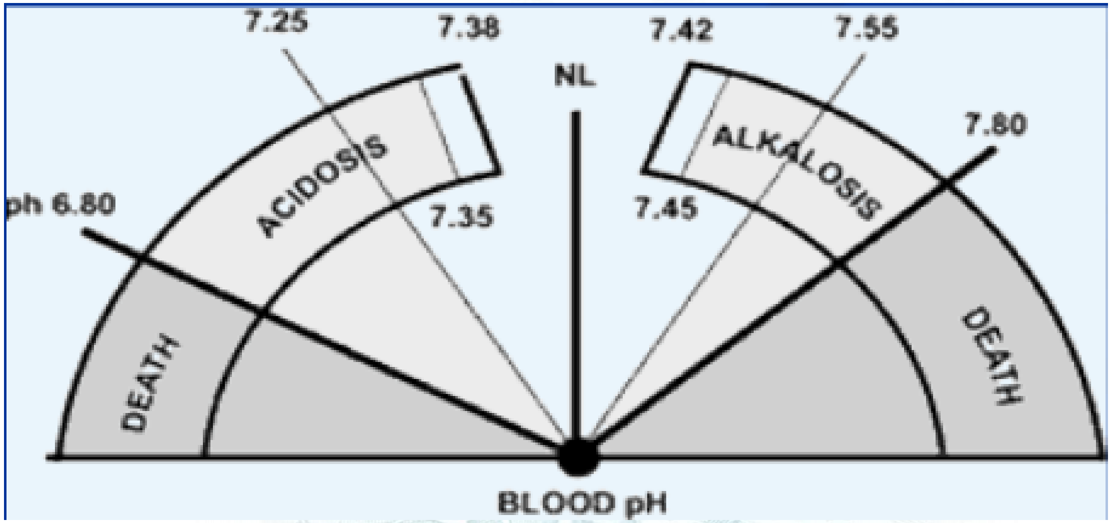

Components of the bicarbonate buffer
kidney
lungs
metabolic component
respiratory component
pH ~ $[HCO_3^-]$ / pCO_2


CO_2
4
1
2
3
$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

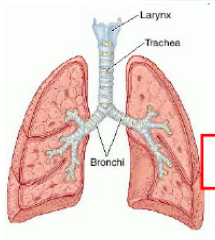

External convection
Pulmonary diffusion
Internal convection
Tissue diffusion
Control centers in medulla
Motor output to respiratory muscles
O_2 sensor
CO_2
pH
Chest wall
Lung
O_2
Hb
Right heart
Left heart
Hb • O_2
H^+
HCO_3^-
Hb • CO_2
Cell

- secrezione H^+
- riassorbimento Na^+
- escrezione HCO_3^-
- secrezione di NH_4





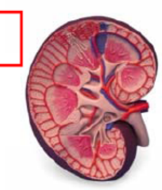
…Interpretazione al Volo…



Compenso rapido

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$

Compenso lento



pH

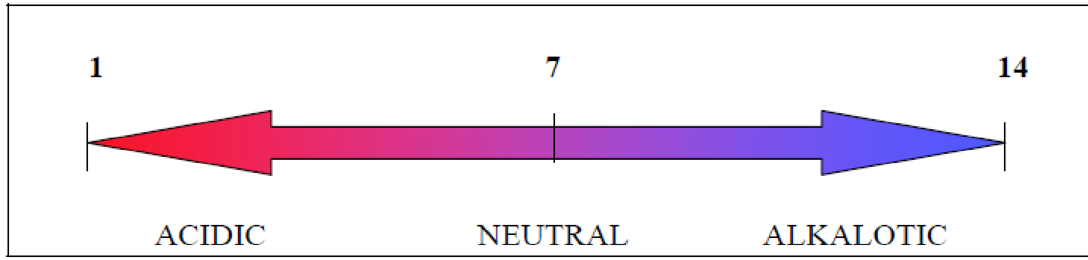
Measurement of acidity or alkalinity, based on the hydrogen (H^+) ions present.

The normal range is 7.35 to 7.45

Remember:

pH > 7.45 = alkalosis

pH< 7.35 = acidosis



$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

pCO_2

The amount of carbon dioxide dissolved in arterial blood.

The normal range is 35 to 45 mm Hg.

Remember:

pCO_2 >45 = acidosis

pCO_2 <35 = alkalosis

HCO_3

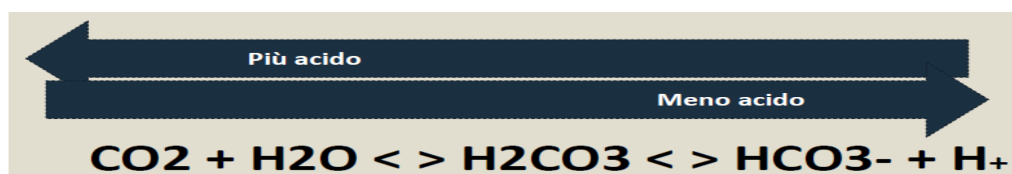
The calculated value of the amount of bicarbonate in the bloodstream.

The normal range is 22 to 26 mEq/liter

Remember:

HCO_3 > 26 = alkalosis

HCO_3 < 22 = acidosis



Step One

Identify whether the pH, pCO2 and HCO3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.30	(7.35-7.45)
pCO_2	55	(35-45)
HCO_3	26	(22-26)

The two matching values determine **what** the problem is. In this case, an **ACIDOSIS**

Step Two

If the ABG results are abnormal, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.30	(7.35-7.45)	ACID	
pCO_2	55	(35-45)	ACID	= Lungs
HCO_3	26	(22-26)	NORMAL	= Kidneys

Match the two **abnormalities**: Respiratory (lung problem) + Acidosis = ***Respiratory Acidosis.***

D.Penzo

Example One:

John Doe is a 55 year-old male admitted to E.D. with recurring bowel obstruction.
He has been experiencing intractable vomiting for the last several hours despite the use of antiemetics.

pH	7.50	(7.35-7.45)
pCO_2	42	(35-45)
HCO_3	33	(22-26)

Step One

Identify whether the pH, pCO2 and HCO3 are abnormal. For each component, label it as “normal”, “acid” or “alkaline”.

The two matching values determine **what** the problem is. In this case, an **ALKALOSIS**

Step Two

If the ABG results are abnormal, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.50	(7.35-7.45)	ALKALINE	
$PaCO_2$	42	(35-45)	NORMAL	= Lungs
HCO_3	33	(22-26)	ALKALINE	= Kidneys

Match the two **abnormalities**: Kidneys (metabolic) + Alkalosis = ***Metabolic Alkalosis***

Example 4

Jane Doe is a 19 year-old female admitted to your …. with **head injury**. Her blood gas results are as follows: pH 7.38, pCO2 56, HCO3 35.

pH is <7.40

ACIDOSIS

pH	7.38	(7.35-7.45)
$PaCO_2$	56	(35-45)
HCO_3	35	(22-26)

Step One

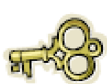
Identify whether the pH, pCO2 and HCO3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

Step Two

If both the pCO2 and the HCO3 are abnormal, but the pH is in the normal range, look at the pH again. Instead of using a "normal range" of 7.35-7.45 as we have been doing, we are going to use the single value of **7.40** as our only "normal". Any pH of <7.40 is now going to be considered acidosis. Any pH > 7.40 is now going to be considered alkalosis.

Look at our pH in this example. The **pH is <7.40**

The two ***matching*** values determine **what** the problem is. In this case, an **ACIDOSIS**



Key Concept:

We only use a single value of 7.40 as "normal" when *both* the pCO_2 and HCO_3 are abnormal (indicating that some degree of compensation exits) and the initial pH is normal.

Step Three

Now, for the two *matching* values, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory)

pH	7.38	(7.40)	ACIDOSIS
$PaCO_2$	56	(35-45)	ACIDOSIS = Lungs
HCO_3	35	(22-26)	ALKALOSIS

Match the two **abnormalities**:
Respiratory (lungs) + Acidosis =
Respiratory Acidosis

Finally, we need to determine if the condition is *partially* or *completely* compensated

In the above example, because the pH is **7.38** (within the range of 7.35-7.45), the condition is **fully compensated**.
Our final arterial blood gas analysis indicates that we have a ***Compensated Respiratory Acidosis***

Key Concepts:

Sometimes, the system that is compensating (respiratory or metabolic) may either have not had sufficient time to correct the situation, or is unable to completely compensate for the degree of abnormality present.

- If the pH is between 7.35-7.45, the condition is *fully compensated.*
- If the pH is outside the range of 7.35-7.45, the condition is only *partially compensated.*
- Remember, neither buffer system has the ability to overcompensate!

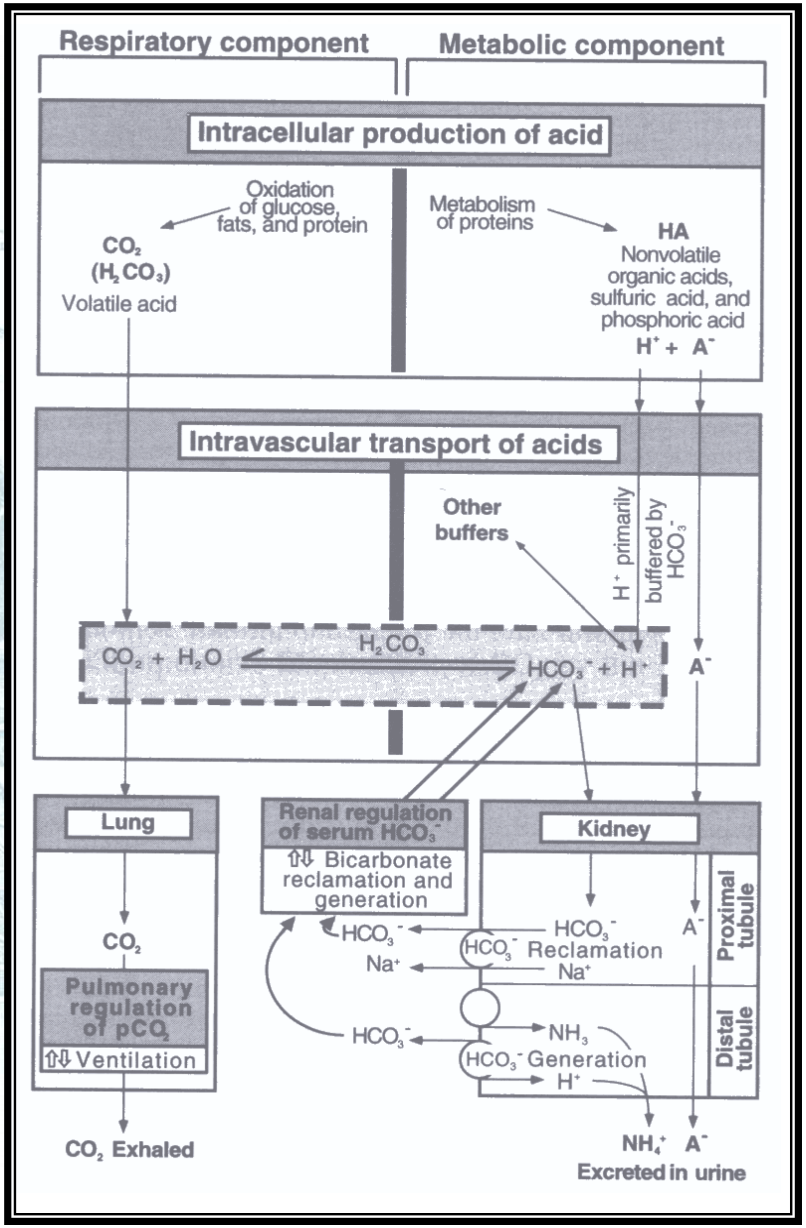
BE (Base Excess)

❖ quantità di acido o di base necessaria per riportare il pH a 7.4 in un campione di sangue equilibrato con PCO2=40, T 37° c

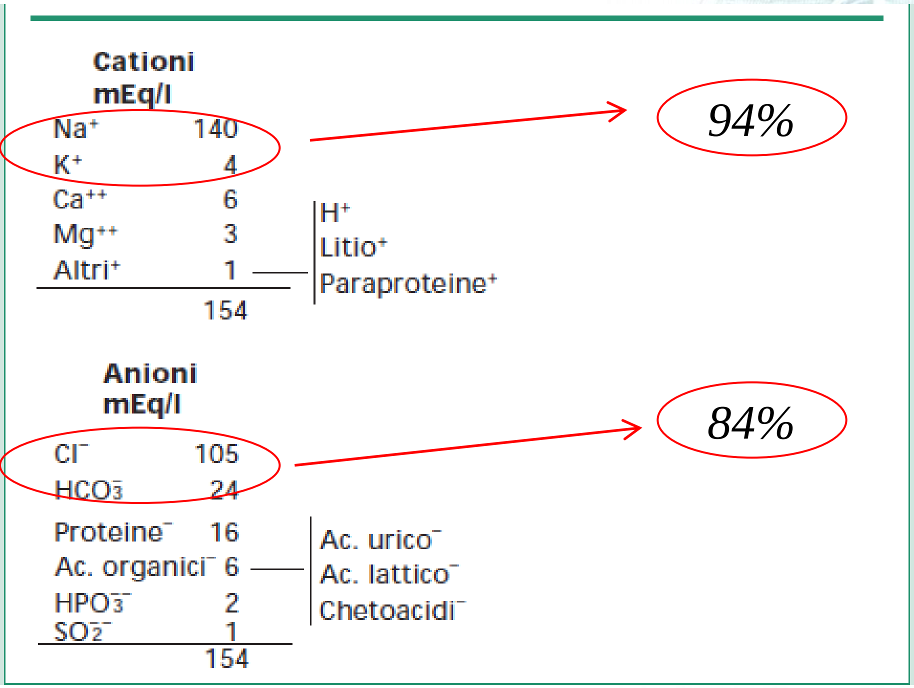
❑ ***Base excess*** *is defined as the amount of strong acid that must be added to each liter of fully oxygenated blood to return the pH to 7.40 at a temperature of 37°C and a* pCO_2 *of 40 mmHg*

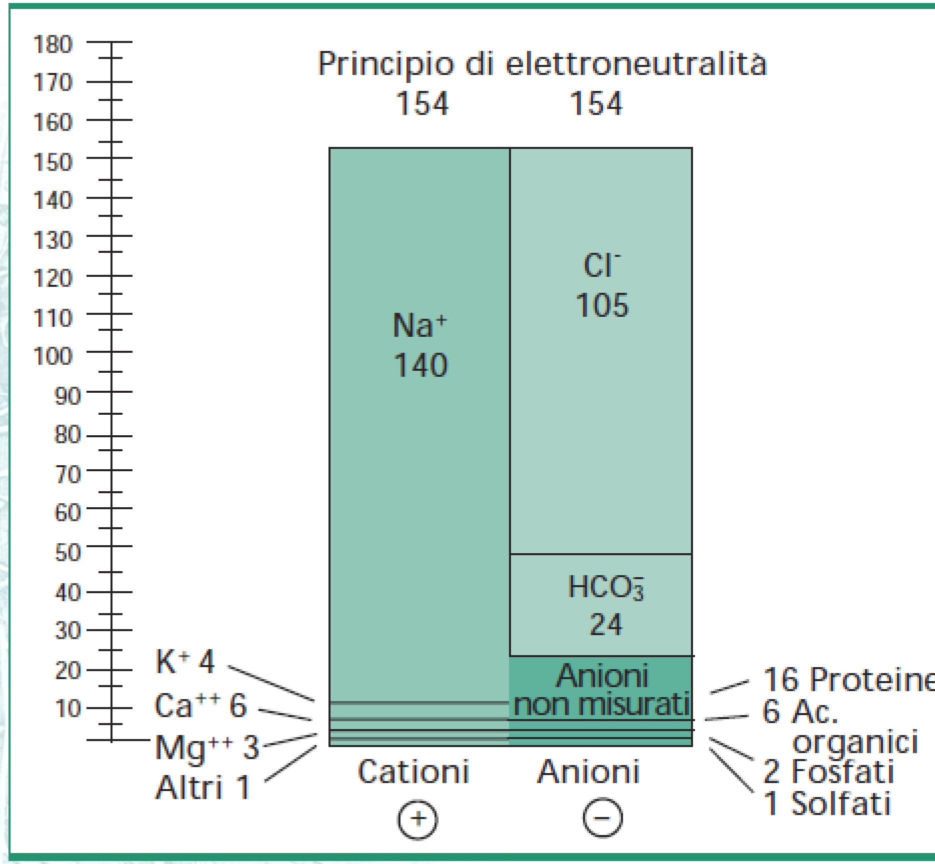
❑ ***A base deficit*** *(i.e., a negative base excess) can be correspondingly defined in terms of the amount of strong base that must be added*

BE (VN ± 2)



ANION GAP





cariche negative devono essere controbilanciate da un pari numero di cariche positive

$$Na^+ + K^+ + CNM = Cl^- + HCO_3^- + ANM$$

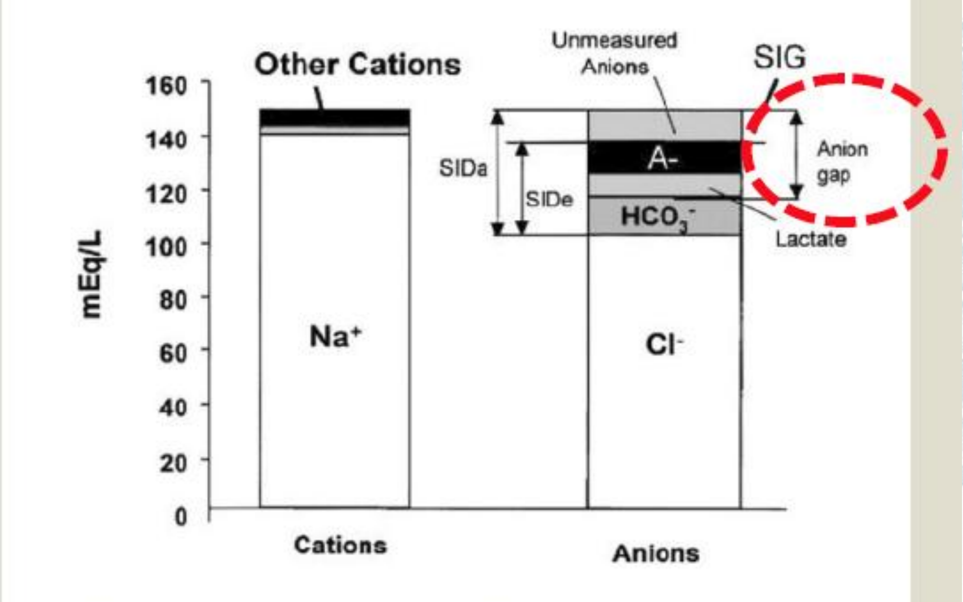
$$(Na^+ + K^+) - (Cl^- + HCO_3^-) = (ANM - CNM)$$

94% 84%

Se la somma di tutti i cationi misurati (Na+ e K+) è sempre superiore alla somma degli anioni misurati, la loro **differenza** esprimerà una quota importante degli altri ***anioni presenti ma non misurati***

$$(Na^+ + K^+) - (Cl^- + HCO_3^-)$$

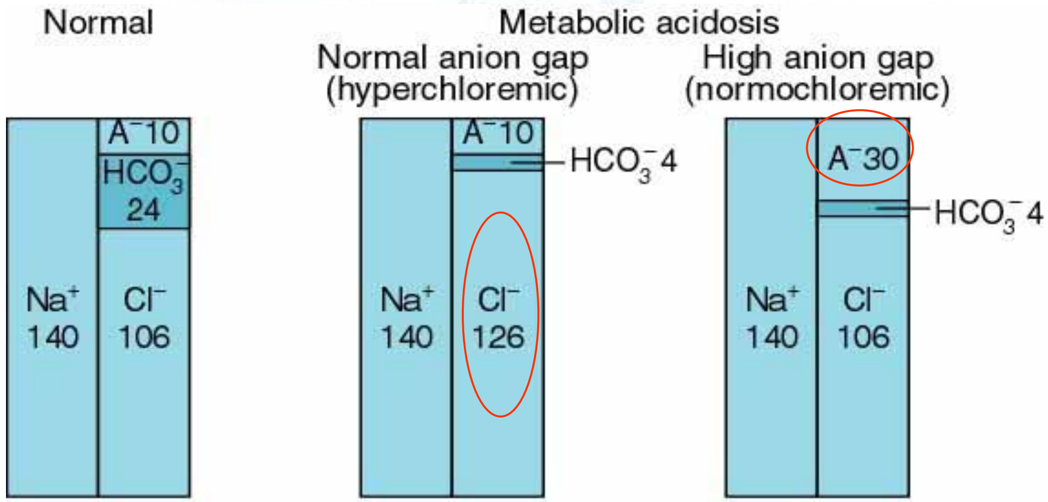
$$(140 + 4) - (105 + 24) = 15 \pm 3$$



Charge balance in human plasma. SIDa, apparent strong ion difference; SIDe, effective strong ion difference; SIG, strong ion gap.

❖ Valutazione dei pz che presentano **un'acidosi metabolica,** allo scopo di determinare se il problema sottostante sia un accumulo di idrogenioni o una perdita di bicarbonato

Gap anionico e tipi di acidosi metabolica



Causes	Causes
Renal acidification defects	Endogenous acid load
Proximal renal tubular acidosis	Ketoacidosis
Classic distal tubular acidosis	Diabetes mellitus
Hyperkalemic distal tubular acidosis	Alcoholism
Early renal failure	Starvation
Gastrointestinal loss of bicarbonate	Uremia
Diarrhea	Lactic acidosis
Small bowel losses	Exogenous toxins
Ureteral diversions	Osmolar gap present
Anion exchange resins	Methanol
Ingestion of $CaCl_2$	Ethylene glycol
Acid infusion	Osmolar gap absent
HCl	Salicylates
Arginine HCl	Paraldehyde
Lysine HCl	

AG NORMALE

(perdita di HCO3)

- ***DIARREA***
- ***INS. RENALE*** *(fase iniziale: perdita di bicarbonati nelle urine)*

AG AUMENTATO

(accumulo di H+)

- ***ACIDOSI LATTICA***
- ***CHETOACIDOSI***
- ***INS. RENALE*** *(diminuita escrezione di H+)*

D.Penzo

Stewart "approach"_ SID

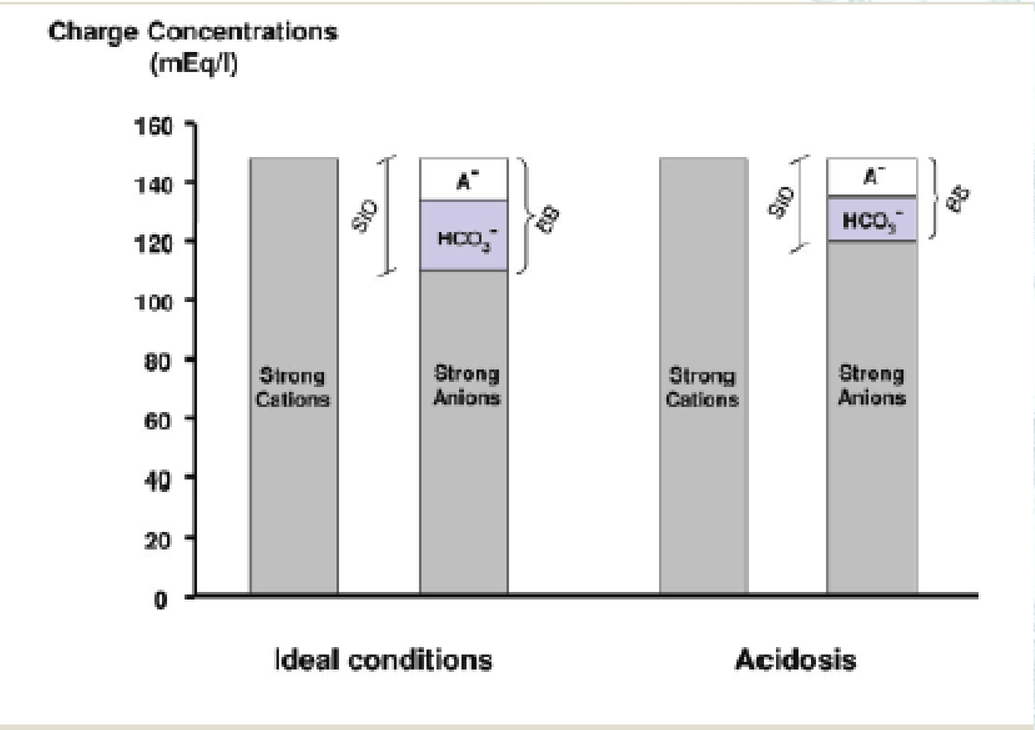


Table 2 Strong and weak ions.

Strong ions	Weak ions
Na^+	HCO_3^-
K^+	HPO_3^{2-}
Mg^{2+}	Albumin⁻
Ca^{2+}	
Cl^-	
SO_4^{2-}	
Lactate	

*…proposed an approach based primarily on charge differences between **strong cations** and **anions**.(<u>Principals of Electroneutrality and Conservation of Mass</u>).*

$$pH = pK + \log \frac{[HCO_3-]}{SXPCO_2}$$

$[H+]$ as a function of the ratio between the HCO_3^- / $paCO_2$

Stewart: …HCO_3^- is a dependent not a independent variable .

<u>The indipendent VARIABLES responsible for changes in acid-base balance are:</u>

- **STRONG IONE DIFFERENCE (SID)**
- **plasma concentration of NON VOLATILE WEAK ACIDS or BUFFERS**
- **$paCO_2$**

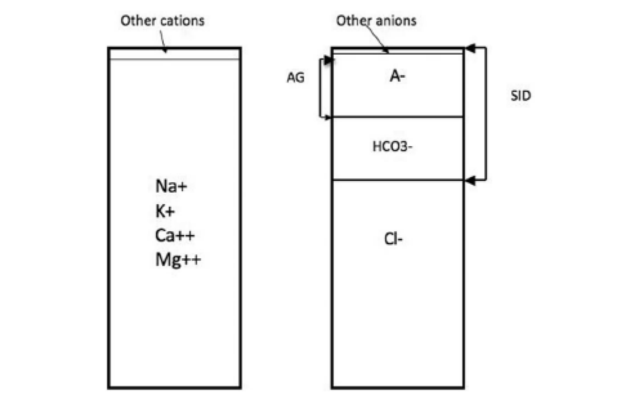


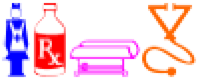
Figure 1. Relationship between SID, anion gap (AG), and bicarbonate in normal individuals.

*The major practical difference between the Stewart approach and the conventional approach to A-B disturbances is the <u>inclusion of the serum **ALBUMIN**</u> in the Stewart approach.*

OSSIGENAZIONE

❑ *Il compito primario fisiologico del sistema cardiovascolare è di trasportare sufficiente ossigeno (O2) per rispondere alla domanda metabolica dell'organismo.*

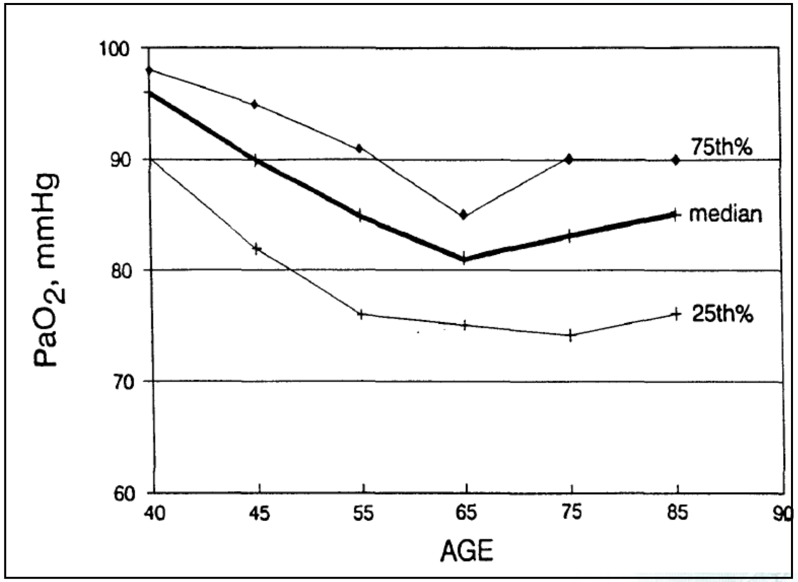
- *Collecting*
- *Handling*
- *Analizing*



<u>Potential Preanalytical Errors</u>

- ✓Non arterial samples
- ✓Air bubbles
- ✓Inadequate or excessive Anticoagulant
- ✓Delayed analysis of a noncooled sample

❖ > 70 anni la correlazione età paO2 scompare



Hypoxemia: *paO2 < 70-80mmHg*

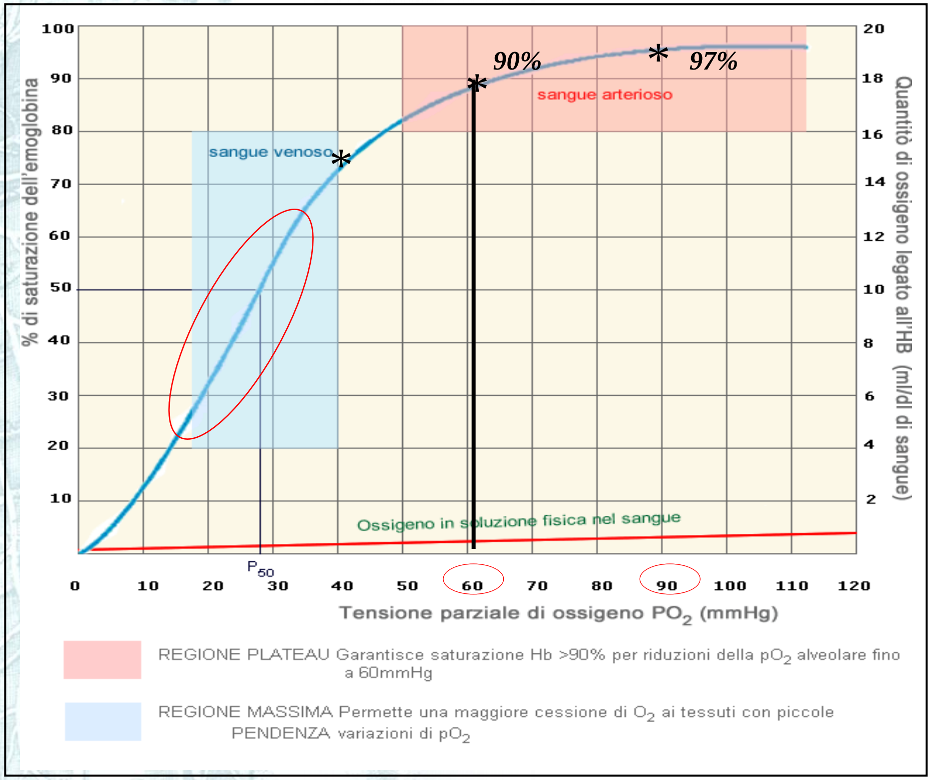
SaO2 < 95%

❏ **paO_2 / FiO_2**

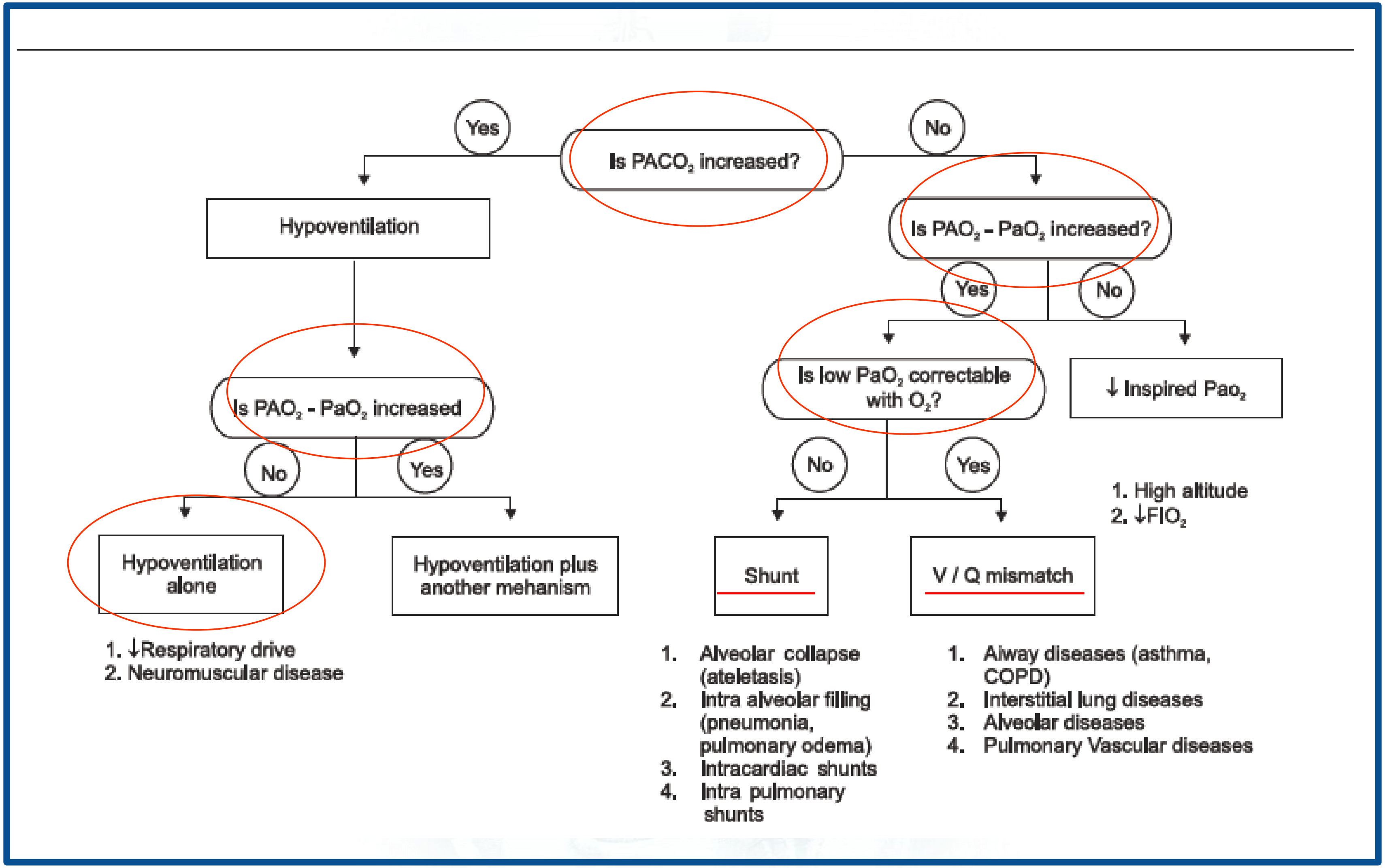
< 200 : severe HYPOXEMIA

(Es. paO2 60 mmHg /FiO2 0.5 =120)

❖Conditions that keep the oxygen molecule **tightly attached** to hemoglobin include *hypothermia, alkalosis, low PCO2, and decrease in 2,3-DPG*
(SHIFT TO LEFT)



❖Conditions that cause **enhanced** release of the oxygen molecule include *acidosis, fever, elevated CO2 levels, and increased 2,3-diphosphoglycerate*
(SHIFT TO RIGHT)



Flow Diagram showing approach to ipoxemic respiratory failure

D.Penzo

IPOSSIA TISSUTALE

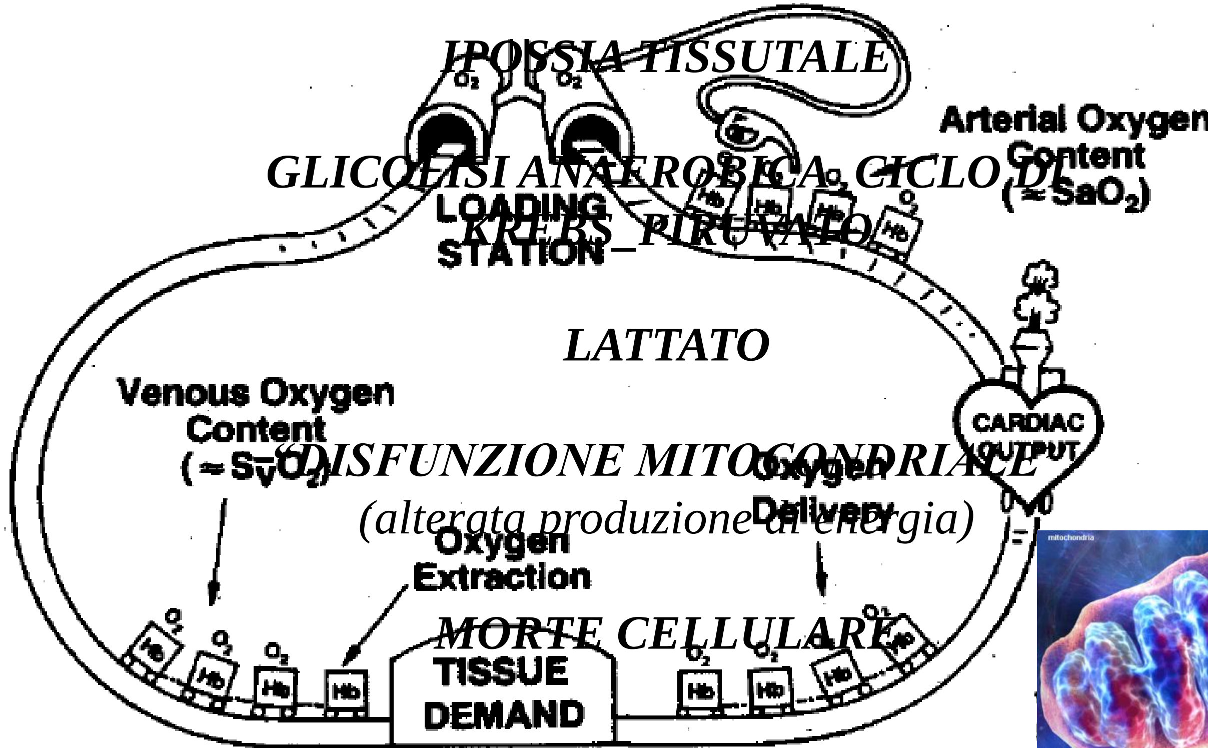
GLICOLISI ANAEROBICA, CICLO DI KREBS, PIRUVATO

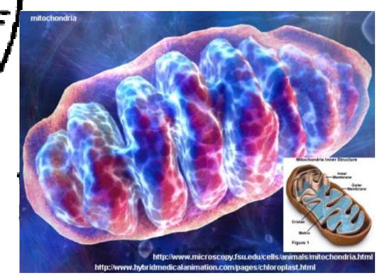
LATTATO

"DISFUNZIONE MITOCONDRIALE"

(alterata produzione di energia)

MORTE CELLULARE



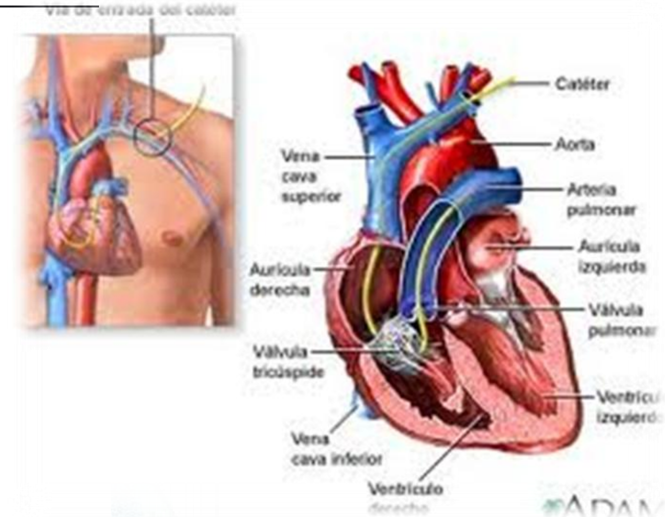


❑**OXYGENATION** is the process of oxygen diffusing passively *from the alveolus to the pulmonary capillary* ,where it binds to Hb in red blood cells or dissolves into the plasma. (Insufficient oxygenation is termed HYPOXEMIA)

❑**OXYGEN DELIVERY** is the rate of O2 transport *from the lungs to the pheriferal tissues*

❑**OXYGEN CONSUMPTION** is the rate at which *O2 is removed from the blood* for use by the tissues

$SvO_2 > 75\%$	Estrazione normale Apporto di O_2 > Richiesta di O_2
$75\% > SvO_2 > 50\%$	Estrazione compensatoria Aumento della richiesta di O_2 o riduzione dell'apporto di O_2
$50\% > SvO_2 > 30\%$	Esaurimento dell'estrazione Inizio dell'acidosi lattica Apporto di O_2 < richiesta di O_2
$30\% > SvO_2 > 25\%$	Acidosi lattica severa
$SvO_2 < 25\%$	Morte cellulare



❑ ***Diminuzione $S\bar{v}O_2$***

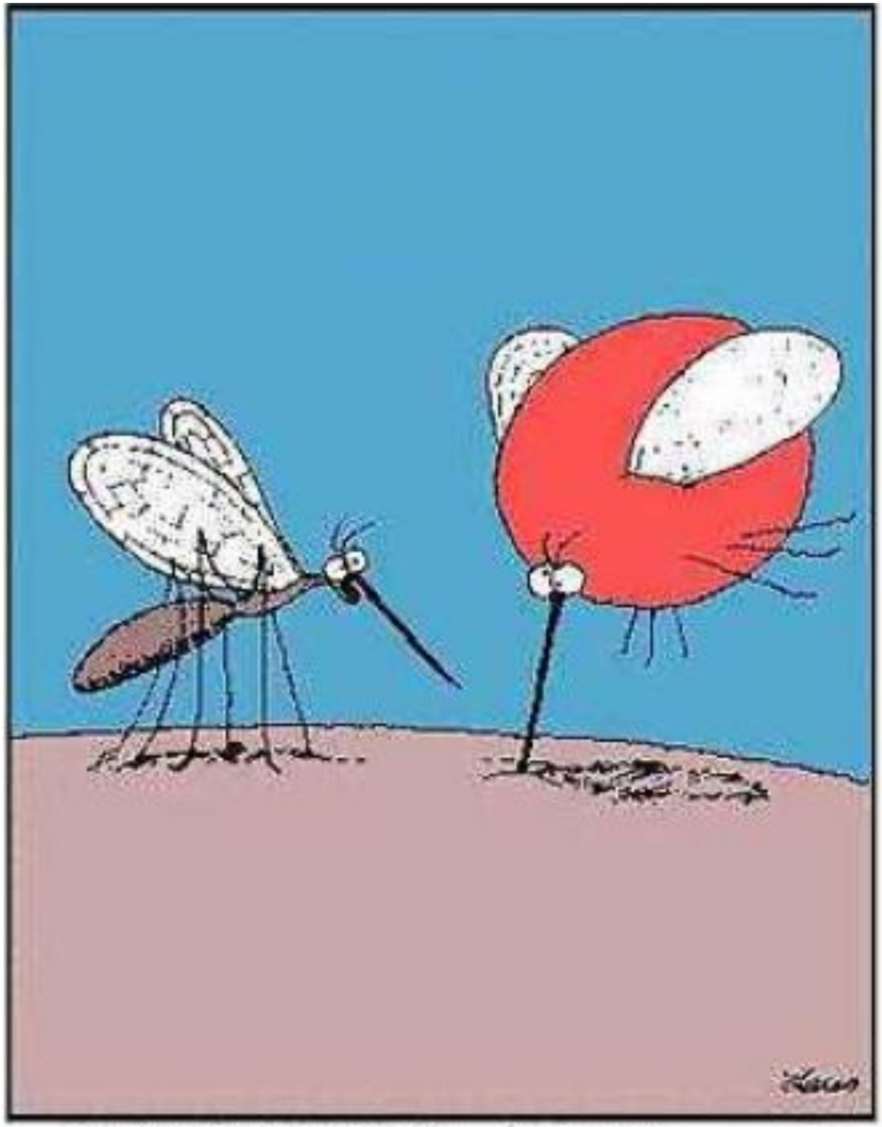
- Anemizzazione (< Hb)
- Low Cardiac Output
- Desaturazione arteriosa
- > Cosumo di O2

…sarebbe utile se la ScvO2 potesse funzionare come surrogato dell'SvO2…

✓*La **ScvO2** abitualmente è inferiore alla **SvO2** di circa **2%-3%** in quanto le parti inferiori del corpo estraggono meno O2 rispetto alle parti superiori determinando così una maggior saturazione di O2 nella vena cava inferiore*

✓*Nello **shock settico** la **ScvO2** è spesso maggiore della SvO2 di circa **l'8%***

✓ *Nonostante la differenza variabile tra i due valori, **cambiamenti nella SvO2 si associano a variazioni simili della ScvO2***



Pull out, Betty!! Pull out… You've Hit an artery!!

Grazie per

L' attenzione