# URO-GENITAL SYSTEM

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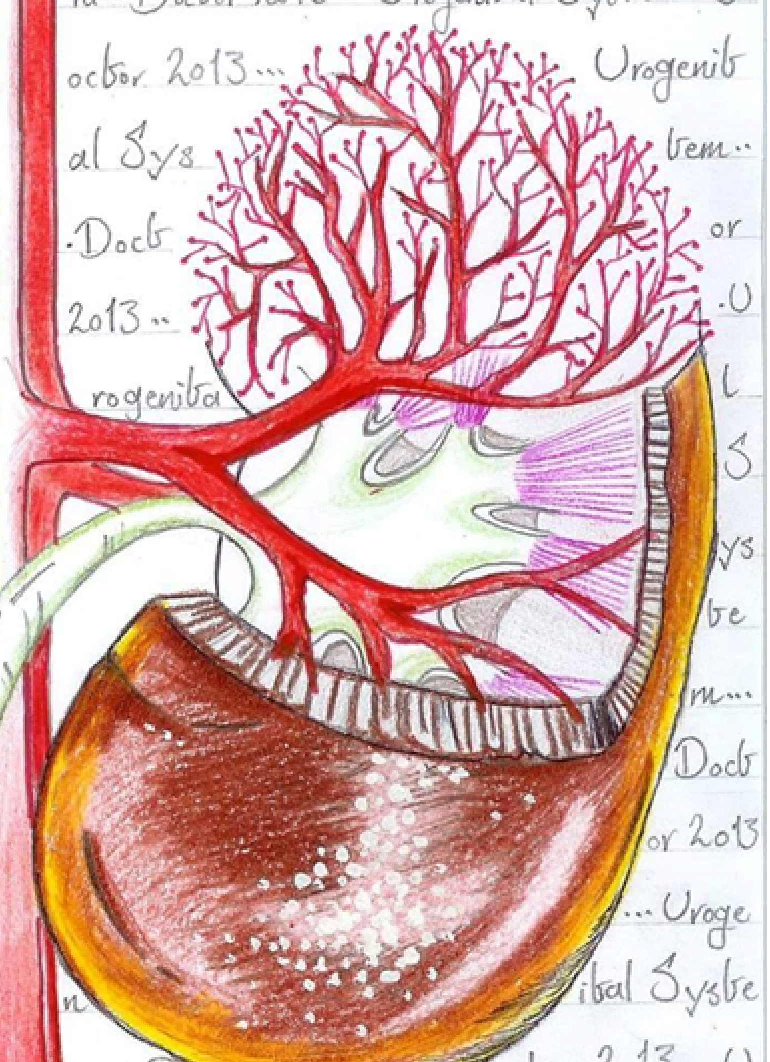


Done By: **Mohanned Momani**

Dr. Name: **Dr. Yanal**


Lec. #: **8**

Drawn By Tariq Bushnaq...

# Acid base balance, part1

This lecture was done according to sec1

You can refer to our chemistry 104 course if you didn't understand any part of it. Because they are pretty much the same.

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This is one of the most important subjects in renal physiology. We are going to spend only 2 lecture talking about it, so make sure you understand it well.

## • [H+]

As we all know, H+ regulates the acidity of body pH, any decrease or increase of its value will be reflected on vitals' performance intensely.

[H+] in our ECF is around 40nM/L

However, this value can decrease or increase up to 4 times and still be compatible with life. i.e. may reach 10 or 160 nM/L

## • pH

Before discussing further calculation let's review some of the old equations we studied before, in order to appreciate the effect of any disturbance in these ions on our pH

-Log = p

Log $10^9$ = 9

And since $[H^+]$ is so small (40nM) we take the Log of its value

= 40nM which is = $40 * 10^{-9}$

= $4 * 10^{-8}$

And by taking the log of $4 * 10^{-8}$;

log 4 + log $10^{-8}$

0.6 + -8

= -7.4

Since the log for [H] = -7.4 it means that the p for [H]= 7.4

Normal pH; ranges from (7.35 to 7.45) *venous blood is more acidic than the arterial*

And as we said before, $[H^+]$ can be • 10nM → pH = 8

• 160nM → pH = 6.8

Any value less or more than that can cause alkalosis or acidosis respectively

Those changes can be fatal, that our enzymes need optimal pH

Acidosis can suppress CNS enzymes leading to coma and death

Acidosis also affects electrolytes' balance as well; increase in cellular $Ca^{++}$ & plasma K, Cl…

Alkalosis can stimulate respiratory muscle(it decreases $Ca^{++}$) leading to convulsions of the respiratory system which cause death

- **Acids in our body**

Our body converts the majority of $H^+$ into$CO_2$ because it's more stable and easily removed from our system.

By hyperventilation you wash out all the CO2(all the acid) and cause yourself a deadly alkalosis

We produce 2 types of acids in our body as a result of metabolic byproducts,

1) Volatile acids, the ones which are removed by respiration like $CO_2$, **each day we produce300 L/D corresponds to 10 M/D(negligible amount)**
2) Nonvolatile acids, like $PO_4$, lactic acids, crisp cycle acids…we produce 1mMol/KG (so an 80Kg person produces 80mMol)

   The latter are more dangerous because in order for them to be excreted and removed from our system they must first be converted to volatile acids like $CO_2$

All acids are eventually dissociate into $H^+$ and their conjugated bases, and our body is trying to get rid of the excess $H^+$ to keep the pH within normal ranges; in order to do that $H^+$ must react with a base like $HCO_3$ as shown in this equation

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

- If more H+ is produced in your body: reaction shift to left and CO2 will be eliminated by the lungs and acidosis is corrected.
- but in order to do that $HCO_3^-$ must be provided to shift the reaction

- the doctor thinks of "$HCO_3$" as the gold of our body since,

  –it's valuable for pH balance, and to keep us alive

  –it has limited amount in our body 24mMol/L → 336mMol in the whole body

Human body produces 80mM of nonvolatile acid every day, dividing that by 15(number of liters our body contains) gives you 5.5mM/L

In words; your body adds 5.5mM of a 2-3 pH solution in every liter you have. Which is fatal!

So Godgave you some mechanisms to get rid of this excess H+.

Are they done through lungs?Buffers? Or kidneys? Let us find out,

## • Our normal pH

As we said before; normally we have a pH of 7.4 which is alkaline, so our body is already prepared to fight back acidity at any time.

## • Lung

As we said before in order to be excreted from the lungs it must be converted to volatile acid like CO2, and for that to happen H+ must react with HCO3.Depending on this mechanism alone will consume all our reservoir of HCO3 which will only keep us alive for 5 days! Give or take.

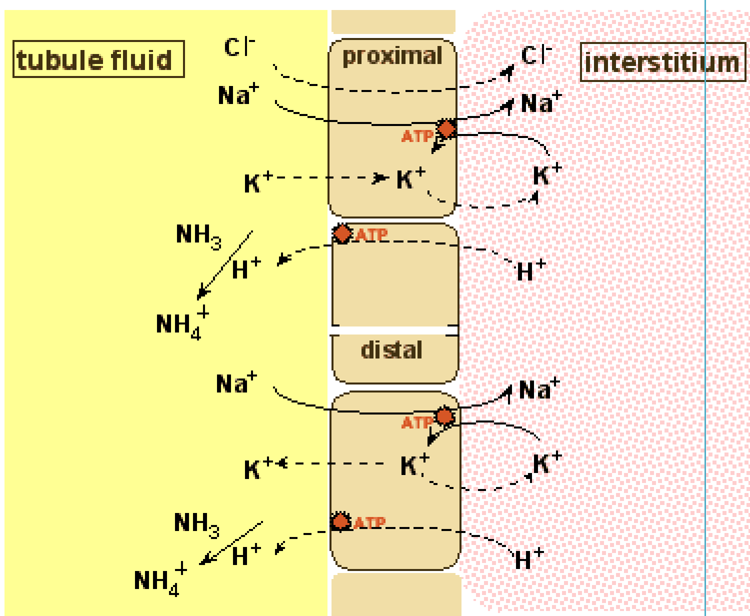
# • Buffers

Truth is, buffers only prevent the sudden change of pH.So its function only delays acidosis or alkalosis, they can never correct our pH back to normal. As we are going to discuss later in this sheet

# • Kidney

H+ are excreted through the nephron by the proximal and the distal tubule

♦in **proximal tubule** it's excreted by counter transport mechanism; in exchange with "$Na^+$" making the pH inside the tubule = 6.5 and outside it (in the interstitium) = 7 *which is not enough*. Keep in mind this is a 2ndary active transport not primary (no ATP usage)




♦in **distal tubule** it's excreted from the interstitium by $H^+$ pump making intratubular lumen more acidic by 1000 times, i.e. making the pH in the urine 4.5 and outside in the peritubular vessels 7 *4.5 is the lowest pH urine can ever reach, keep that in mind the doctor said this number is important!*

A pH of 4.5 corresponds with 0.1mMol of $H^+$, which is not enough because we need to get rid of 80!. So excretion by urine is not efficient.

♦consider HCO3 reabsorption for a second, as we said HCO3 is so valuable we can't allow of its excretion; recap that [HCO3]=24mMol. The filter load of HCO3 per day is → 80*24mMol=4320mMol. All of it is being reabsorbed, and this is the most important function of the kidney,

♦kidney also can produce HCO3 in the blood, this is the main mechanism to get rid of H+ but unfortunately this function needs time to responds, so lungs and buffers only buy us some time till the kidneys produce HCO3

So if you were asked about renal venous blood, keep in mind that it has more renin &$HCO_3$

So to fight acidosis we have 3 main lines,

1) buffers→fast working
2) lungs → very efficient but moderate speed, needs hours to give a full response
3) kidney→ is the best and the most important, but the slowest! Needs days to give a full response

## ♦Buffer system in the blood

### Buffer Systems in the Body

**Bicarbonate** : most important ECF buffer

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

**Phosphate** : important renal tubular buffer

$HPO_4^{--} + H^+ \longleftrightarrow H_2PO_4^-$

**Ammonia** : important renal tubular buffer

$NH_3 + H^+ \longleftrightarrow NH_4^+$

**Proteins** : important intracellular buffers

$H^+ + Hb \longleftrightarrow HHb$

(60-70% of buffering is in the cells)

We talked about their function in reducing sharp changes in the pH but to appreciate their role let us take an example (next page)

Imagineyou have 2 buckets of water, only one of them has the buffer "HCO3/H2CO3"

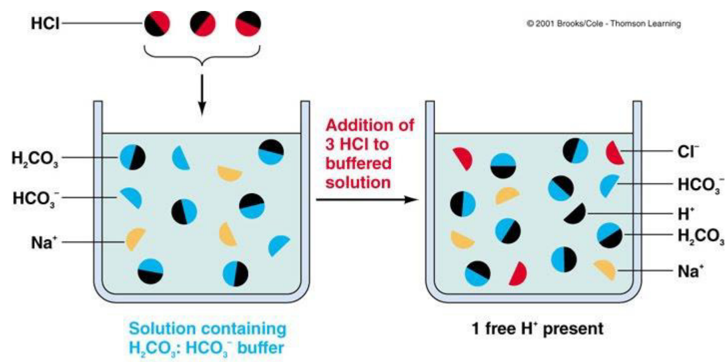
You add some drops of HCl into both of them, now as we know HCl is a strong acid and it will dissociate totally. If you noticed the pH in both of them you'll see that in the one with no buffer the reading is 3 However, the one with the buffer has a pH of 6.5

What happens here -in short- is that buffer reacts with HCl producing a weak acid that will not dissociate completely, and thus give a smaller effect on pH.

HCl + NaHCO3 = NaCl + $H_2CO_3$

So instead of having HCl in the solution, it's replaced by $H_2CO_3$

The following picture is colored so check out the pdf copy




How about adding NaOH instead of HCl? The following reaction will happen;

**$NaHCO_3$ + NaOH → $Na_2CO_3$ + H2O**

So as you can see the buffer here have reacted with the strong base(NaOH) which couldincrease the pH dramatically, and produced a much weaker base($Na_2CO_3$) which has much smaller effect on pH.

Now let's look at each buffers' equation and see their actual effect on our pH

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

To calculate the pH of our body, given that [**$HCO_3$]=24mMol and [CO2] =12mMol**

$$pH = pK_a + \log \frac{[HCO_3]}{[CO_2]}$$

$$pH = 6.1 + \log \frac{24mMol}{12mMol}$$

=7.4

$$H_3PO_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + H_2PO_4^-$$

To calculate the pH of our body, given that [ H3PO4]**=1mMol and [H2PO4]=0.25mMol**

$$pH = pK_a + \log \frac{[H_3PO_4]}{[H_2PO_4]}$$

$$pH = 6.8 + \log \frac{1mMol}{0.25mMol}$$

=7.4

Same results will happen for the rest of our buffers

From the previous equations you can see that all buffer systems in our body tend to maintain the pH at 7.4

The doctor talked about this slide

## Classification of Acid-Base Disorders from plasma pH, $pCO_2$, and $HCO_3^-$

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

$$pH = pK + \log \frac{HCO_3^-}{\alpha \; pCO_2}$$

**Acidosis** : $pH < 7.4$

- metabolic : $\downarrow HCO_3^-$
- respiratory : $\uparrow pCO_2$

**Alkalosis** : $pH > 7.4$

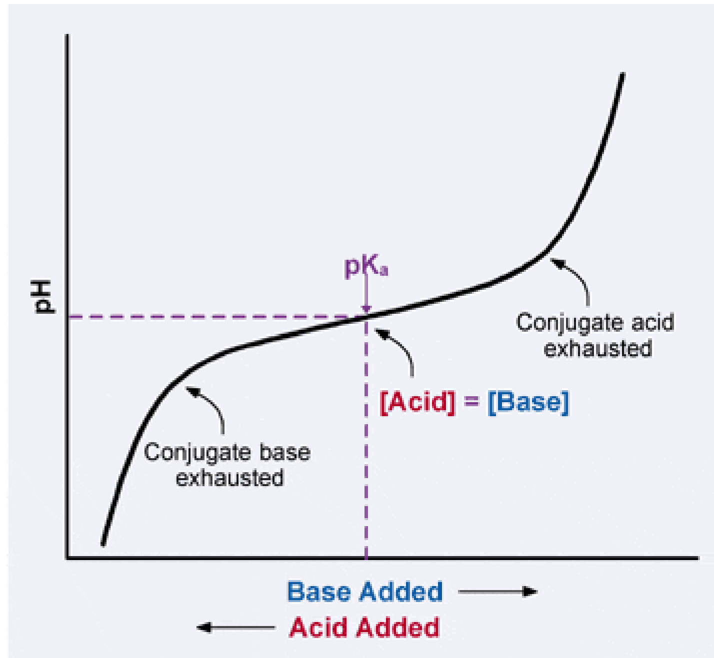
- metabolic : $\uparrow HCO_3^-$
- respiratory : $\downarrow pCO_2$

It's always better to give a buffer with the closest **pka** to the solution **pH**, i.e. if the pH=pka the buffer works on its optimal functioning,

Pka means: pH of the solution when the acidic and the basic form of the buffer are equal

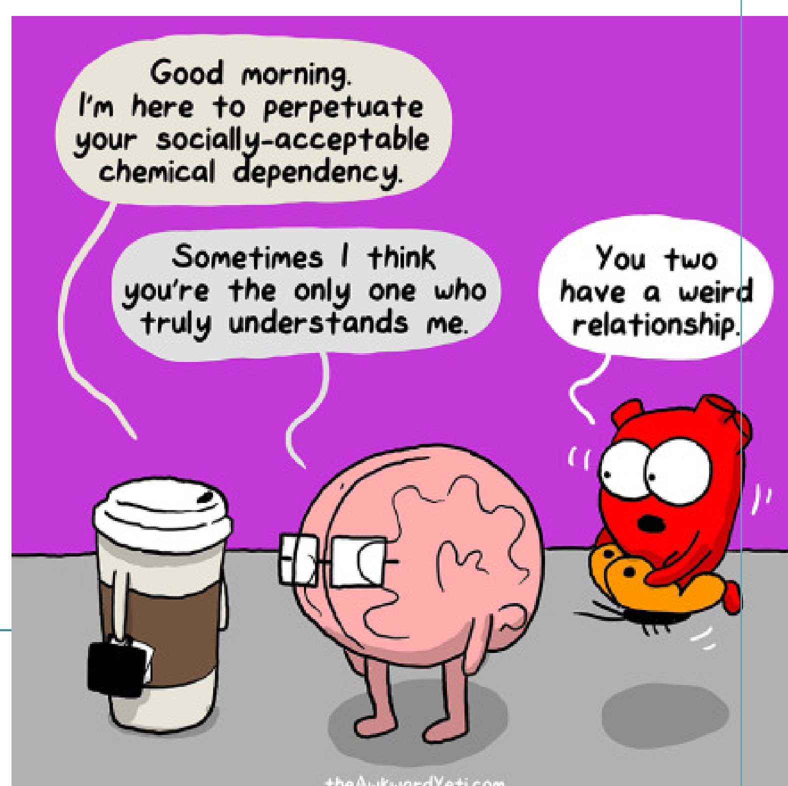
Regarding this figure let us first note some important findings to understand more how the buffer work

1) As you can see there is some sort of plateau in the middle, at the point where pH=pka, meaning; our buffer is doing its job wonderfully by preserving the pH and keeping it from rising or falling rapidly




2) When the pH is getting far away from pka value you can see how the sudden rise/fall in the pH of the solution after adding more acid/base
   • One can only assume that the buffer has lost its function when the pH of the solution was far from the pka,
   Thankfully our buffer system is well adjusted to any change and can help in preserving the pH until other mechanisms jumps in to correct the imbalance.

Done by; Mohanned Momani
Dedicated to Nashat Kh




Joke explanation, mainly for Baraa 😜

As it is well known that drugs are socially unaccepted, people ignore the fact that coffee is nothing but a CNS drug that works on the brain producing mental effects like alertness, euphoria and excitement. It also has some side effect like GI disturbances and insomnia. However, it's considered as a normal drink that is commonly served everywhere regardless of its side effects and addictive properties.

In this comic; such fact was noted in a sarcastic way, showing a relationship between the brain and coffee similar to the relationship between addicts and their drugs.

Normal response will be; smiling with small laughter that is represented by breathing faster than usual in a quite manner.