Respiratory system physiology

sheet handout slides

Number	2
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note: this sheet was written and corrected according to the records from section 2 so you may find differences in the arrangement of topics from the records available on the website.

In the previous lecture:

- What are the Potential Causes of Hypoxia?

1. inadequate oxygenation of lungs

- unavailability of o2 in the Atmosphere for example in high altitude
- decrease muscle activity

2.pulmonary disease

3 .inadequate transport

- Anemia, abnormal hemoglobin
- blood flow

4.inadequate usage

- Cyanide

Today we will talk about:

note: this part was taken from the slides without any change .

- What is respiration?
  - Respiration = the series of exchanges that leads to the uptake of oxygen by the cells, and the release of carbon dioxide to the lungs

Step 1 = ventilation

- Which includes: Inspiration & expiration

Step 2 = exchange between alveoli (lungs) and pulmonary capillaries (blood)

- Referred to as *External Respiration*

Step 3 = transport of gases in blood

Step 4 = exchange between blood and cells

- Referred to as *Internal Respiration*
- Cellular respiration = use of oxygen and ATP synthesis

note: the professor started today lecture here

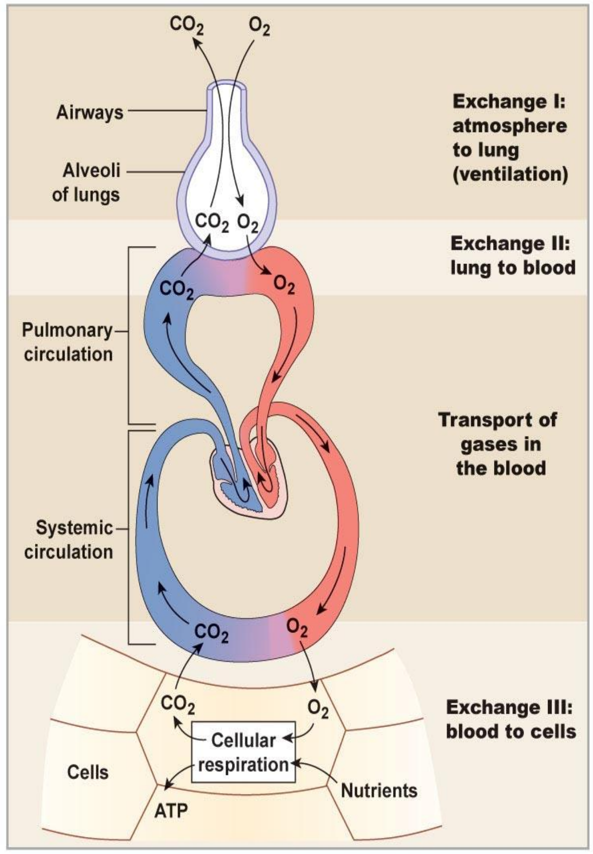
arterial blood gases: (ABG):

PO_2=100

PCO_2=40

We want to see how this is accomplished inside the arteries??

note: when we say arterial blood gases we are talking about the pressure of gases in the arteries right after they get oxygenated in the lungs.



Atmospheric pressure = 760mmHe at sea level.

O_2→ 21% of the Atmospheric pressure→160mmHg is the Partial pressure of oxygen in the outside air

N→٧٩% → 600mmHg

CO_2→0.3% **almost zero**

So this is the composition of the atmosphere at <u>sea level.</u>

As we said yesterday, the First cause of hypoxia is <u>unavailability of oxygen</u>.

To understand this better let's look at what happens when someone tries to climb a mountain, For each **5.5km** height, the atmospheric pressure decreases by **one half**. The percentage of oxygen, in contrast, remains constant (21%).

Thus:

-At **5.5 km** height, atmospheric pressure is **380mmHg(760/2).** Partial pressure of oxygen is **21%** of the 380mmHg that is, **80mmhg** (instead of 160mmHg at sea level)

- At **11km** Height, atmospheric pressure decreases by one fourth,**190 mmHg**. Partial pressure of oxygen is 21% of the 190mmHg →**40 mmHg** (very low).

There is no way you can make your O_2 inside =100mmHe.

note: the po_2 in the atmosphere needs to be higher than 100mmhg for the po_2 in the lungs to be 100mmhg so if the po_2 in the atmosphere is 80mmhg or 40mmhg the po_2 in the lungs will be less than 80mmhg and 40mmhg respectively.

The concentration of O_2 AT theses Heights is very low.

Mount Everest is almost 9800 meters high, there is not enough oxygen on the top. Thus, if you stand on top of Mount Everest for an hour without an oxygen supply, you will die.

NOW,

We go inside→ first to the ADS (anatomically dead space), and then to the alveoli.

note: The respiratory system is composed of two zones : The conducting zone : This zone only conducts the air in and out with NO exchange of gases across the wall and Respiratory zone: alveolus surrounded by a huge network of capillaries and that is where the exchange of gases takes place.

Remember that ADS also called the conducting system and there is no gas exchange.

In the ADS the total presser remains 760mmHg whether you have one gas, tow gases. Or 3 gases.

note: the reason behind this is that if we add a new gas its going to replace the other gases and the total pressure will not change in the ads.

Dalton's Law
of Partial Pressures
The total pressure of a mixture of gases is equal to the sum of the individual gas pressures.
What does this mean in practical application?
If we know the total atmospheric pressure (760 mm Hg) and the relative abundances of gases (% of gases)

We can calculate individual gas effects!

For example:
(Patm x % of gas in atmosphere = Partial pressure of any atmospheric gas
PO2 = 760mmHg x 21% (.21) = 160 mm Hg)

In the ADS: we shouldn't call it dead.

Because >>>

1-Makes the inspired air at body temp.

2-adds water vapor (Humidify the dry air)

3-Faltration of the air

So in the ADS we have 3 gases:

1-PH_2O at 37 c = **47mmHg** (this is the maximum)

This is 100% fully saturated air with water vapor you cannot add more vapor at 37c.

Any addition → convers to water

Example: if the temp is 37c and the PH_2O is 23.5mmHe we say that the air is 50% saturated.

If the Temp is 20c and PH_2O= 22mmhg this air is 95% saturated.

(Every temperature has different PH_2O at which we have a fully saturated air)

Note: the doctor assumed that the inhaled air is zero saturated, we ignored the PH_2O because it changes in different areas.

note: make sure you don't confuse the ph2o in the atmosphere that is variable according to the temperature of the air *__the one the professor chose to ignore__* and ph2o which was added in ADS at body temperature which equals 47mmhg.

Now we must calculate the PO_2 again after taking the PH_2O into consideration *the ph2o which was added by the ads*
760-47 =713mmHe
PO_2= 21%*713=**150 mmHg** (in the humidified air in the ads)
PCO_2= zero
Pn2=713-150= 563mmhg or 713*79%= 563mmhg
When we go down, in the alveoli the 02 is going to be up taken so its going to decrease even more, also we add CO_2 so we will have 4 gases:

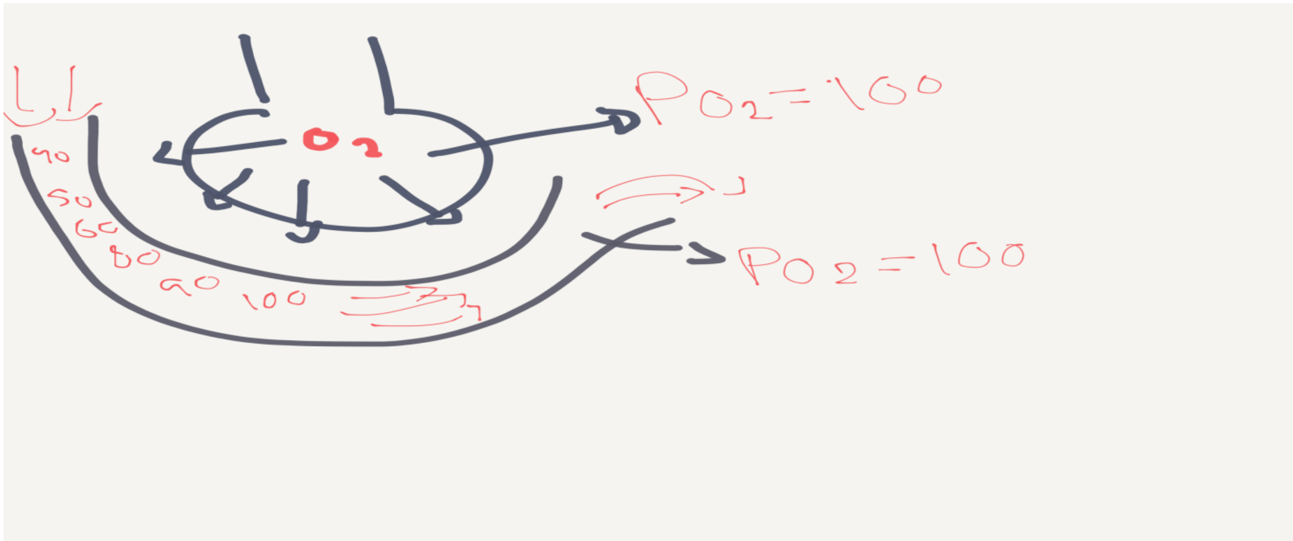
1) **CO_2= 40mmHg**
2) **O2=100mmhg**
3) H_2O= 47mmHe also because,. The temp, in our body <u>is fixed</u>
4) N_2=760-(40+47+100)=573mmHg

(${N_2}$ is a spectator molecule (متفرج), and PH2O is always constant at normal body temp., thus we will not bother with them anymore and just focus on PO2 and PCO2).

From this point we will only talk about the CO_2 and O_2.

	Atmospheric	ADS	alveolar	Arteral	Veins
PO_2	160	150	100	100	40
PCO_2	0	0	40	40	45
PH_2O	0	47	47	47	47
PN_2	600	600	Not important	Not important	Not important

Now ,
We have blood coming from the R.ventricle via the pulmonary artery containing 40mmHg PO_2, and 45mmHg PCO_2.
note: the blood in the pulmonary arteries is **mixed venous blood**.
Blood diffuses and the concentrations within the capillary will increase to(40 , 50,70,80,90 and finally 100mmhg)
So PO_2 when the blood exit the capillary should be 100 mmHg .



You must notes that we used only the first 1/3 of the capillary and 1/3 the respiratory membrane. (it is Enough for exchange)

There is no exchange in the other 2/3.

When we reach equilibrium between the alveoli and the capillary

The PO_2 in both will become 100mmHg. How come? Isn't it supposed to be 140/2= <u>(100 in the alveoli+40 in the capillary)/2</u> = 70 in the capillaries and 70 in the alveoli!?
The answer is NO (they will become 100 –100mmHg)!

-one of suggestions is that oxygen keeps getting inward (what goes from alveoli to capillaries will be replaced directly by oxygen inspired), but …this is not the major cause

If we stopped breathing → no big change will occur.

So..

If you remember from the cardiovascularsys

Blood volume =7% of our body Wight so if the person 70kg

His blood volume will be 5L.

These 5 L are distributed in

1. systemic veins = 3L (3000ml)
2. systemic arteries=750ml
3. Sys.capillaries=350ml
4. Heart = 350ml
5. **Lung 450** → (in the pulmonary artery= 190 , in the pulmonary vein= 190 , in the capillaries= **70ml** only)

   Before you inhale the lung contains **2200ml** of air that's because the inhalation process takes place in a partially inflated lung So this large volume will affect the small volume of the capillary.

   From last year sheet:

- the total volume of the blood in the capillary is very small in comparison with the volume inside the alveolus, so addition of small amount of oxygen to the capillary is sufficient to elevate its oxygen conc.:
- Remember that PO_2 is another way to represent oxygen conc.
- And Conc. = amount/volume. So it's a ratio.
- when you connect two closed systems that differ in their conc. for solute A, this solute will diffuse from higher conc. to lower conc. until it reaches equilibrium.
- so at equilibrium, $C_{Alveolus} = C_{capillary}$, so:

$pO2_{Alveolus} / V_{Alveolus} = pO2_{capillary} / V_{capillary}$

But if $V_{Alveolus}$ is very low, a negligible amount of $O_{2capillary}$ (that will not affect $C_{capillary}$) will diffuse to alveolus and been added to $C_{Alveolus}$, elevating $O_{2Alveolus}$.

- so we conclude that the greater conc. will affect the smaller by shifting the equilibrium near its value.

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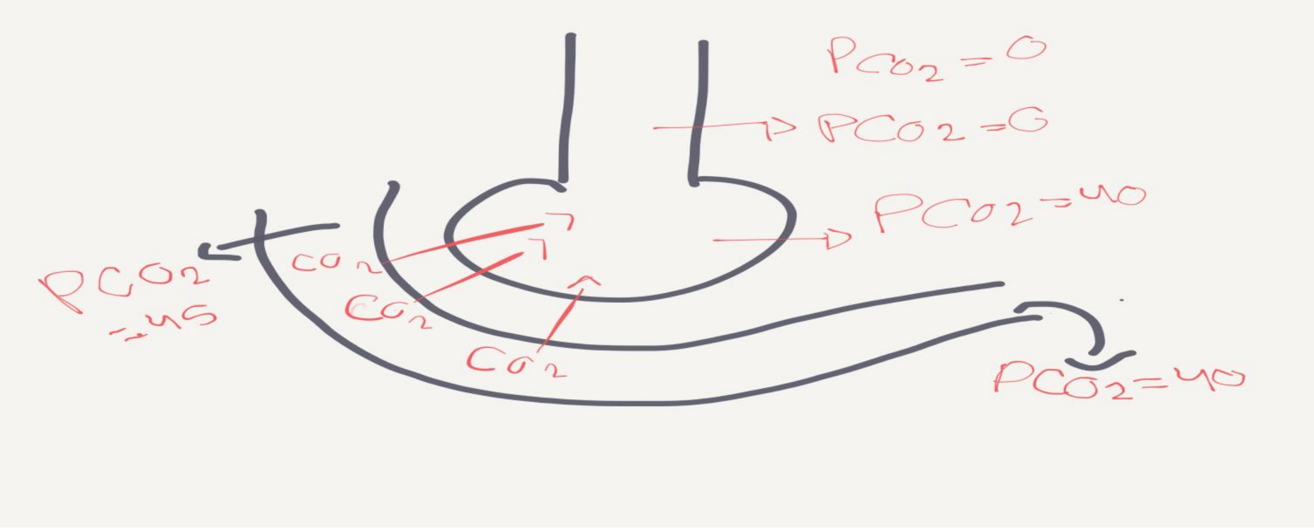
note: as the blood leaves the lungs the difference in the po_2 between the alveolus and the capillaries **theoretically** becomes 0 (100mmhg-100mmhg=0) <u>and since the blood in the capillary can't go back to another alveolus</u> and has to keep moving forward, if the difference in pressure between the alveolus and capillary is anything above 0 than that means we have a **diffusion problem**.

For example: if the alveolar- arterial difference is 20 which mean that we have diffusion problem.

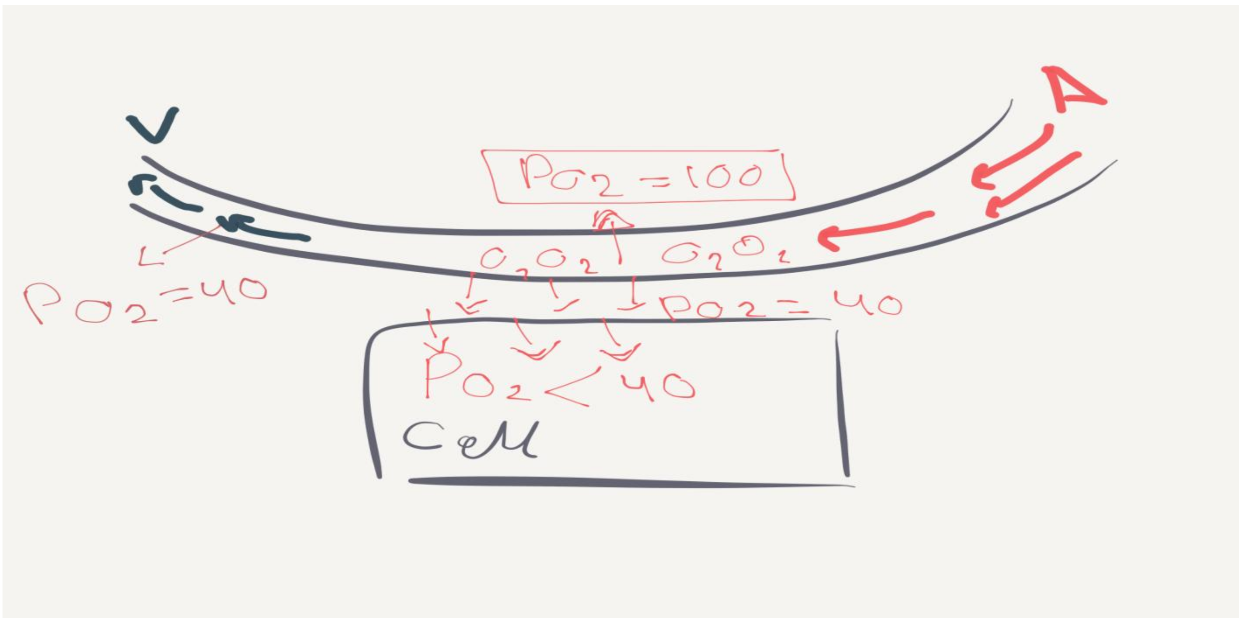
Now CO_2:

Notes the PCO_2 and the PO_2 at the end of the capillary are mirror images to the alveolar concentration.

note: as you can see in the figure below the pco_2 starts at **45mmhg** and decreases as co2 defuses from the capillary to the alveolus to **40mmhg**



Moving to the cell:
PO_2 in the interstitial fluid = **40mmHg**
And PO_2in the artery= **100 mmHg**
So oxygen will diffuse



TBW total body water = 60% in 70kg person = 42L

divided into two compartments.

- Intracellular fluid 2/3 =28L

-Extracellular ½= 14 L → this is also divided to

Interstiti
11L

plasma
3L

These 11 L will affect the 350 ml volume of capillaries so O_2 will diffuse outside of the capillaries until we reach equilibrium and the PO_2 in the capillaries will be the same as the interstitial……**po_2=40mmhg**

note: the PO_2 inside the cell is **less than 40mmhg** creating a gradient for oxygen to diffuse from the interstitial fluid into the cell.

While the PCO_2 inside the cell is more **than 45** so it will diffuse to the interstitial→ to capillaries → carried to the veins

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As you remember CO= SV*HR
In the respiratory sys→ the Respiratory Minute Inhalation (the amount of air we inhale in one minute) = T.V*RR
note: t.v=**Tidal volume is** the normal volume of air displaced between normal inhalation and exhalation when extra effort is not applied……R.R= **respiratory rate**
or we can say:
T.V→ is the amount of air we inhale and/exhale by each cycle (DURING QUITE BREATHING)=**500ml**
As we said we don't inhale in totally collapsed lung →before we inhale we have 2.2L and at the end of inhalation we have 2.7L → and after expiration the volume will go back to 2.2 L.

note: 2.2L +T.V(.5L)=2.7L

ADS volume =2ml/kg of Wight
So if the Wight → 75kg → so the ADSV will be 2*75 =150ml
When we inhale → 500 ml of fresh air pO_2 is 160 and PCO_2 is zero
The first 150 ml of fresh air is going to push the 150 already exists in the ADS .So now the fresh air is in the ADS and if the T.V is only 150 there will be no benefit and the fresh air will not reach the alveoli.
Another 150 enters will push the first 150 and now we have 150ml of fresh air instead of the old air

So alveolar ventilation is actually 350ml whit the 150 old air in the ADS will for 500ml

350 out of 2200 ml is only 1/7 so each time you change the composition of air by less than 15%.

500ml is T.V we will divide it into:

1) ASD →150ml
2) Alveoli AIR → 350ml

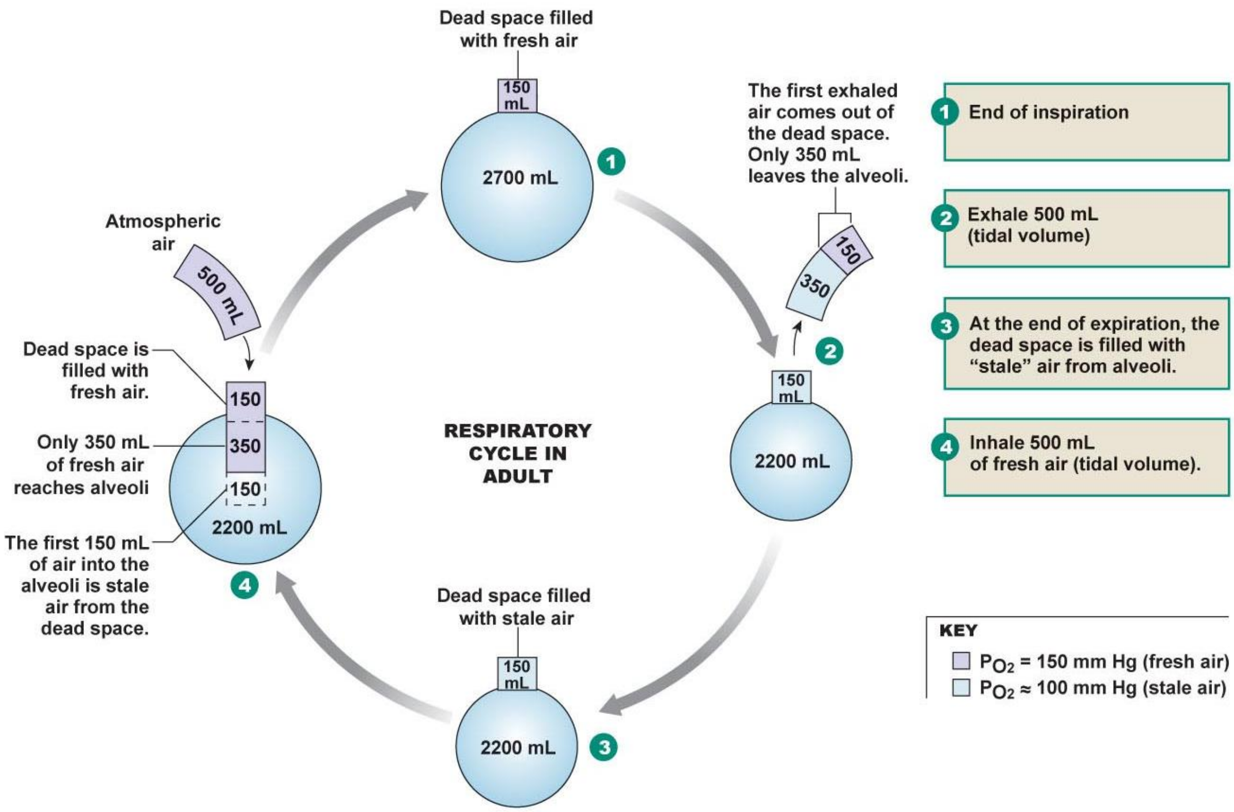
note: that paragraph seemed scary so let's try this again,

1. lets look at the change in volume: when atmospheric air tries to get in its going to collide with the preexisting air in anatomical dead space (keep in mind that the volume in the ADS=2ml*weight in kg so in a 70kg man ADS volume= 150ml) since that space is basically a closed tube the first thing that's going to happen is that 150ml of the atmospheric air are going to displace the air in ADS forcing it to go inside into the alveoli then another 350ml of the atmospheric air are going to lay on top of those 150ml, so at the **end of inspiration** the air in the ADS is actually atmospheric **fresh air and the air** →changes in composition.
2. the air in the ADS is known as black air because it contains po_2=100mmhg and pco_2=40mmhg so black simply refers to its composition and it's the same composition as the air we exhale, and atmospheric fresh air is known as blue air because it contains po_2=160 and pco_2=0 now When the atmospheric air and the preexisting air in the ADS enter the alveoli they mix with the 2200ml of air in the alveoli that has the composition of black air

and since the blue air is very low in comparison they will form black also known as alveolar air so again at the end of inspiration the air in the ads is blue/fresh air and the air in the alveoli is black/alveolar air

Finally lets look at expiration the lung is going to expel 500ml of alveolar air outside, the first thing that's going to happen is that this alveolar air is going to push the fresh air that's in the ads and then replace it, so at the end expiration the **air in the alveoli and in ads will be the same and that is black/alveolar air.**

keep in mind that we only let in 350ml of the blue air into the lung that already had 2200ml In it so were going to change the composition of the lung by a small amount, 350/2200 which is 1/7 and roughly equals 15%.



Cardiopulmonary resuscitation (CPR):

Mouth to mouth berthing

What type of air you are giving to him???

Your Exhaled air but what are the composition of this air???

At the end of inhalation as we said the ADS is filled white fresh air wheal alveolar air is a mixed air PO_2=100

and the PO_2= 150mmHg in the ADS

AT THE END OF Exhalation the composition of the ADS → the same as the alveolar air

So we are giving 500 ml (350ml coming from the alveoli→ where the PO_2 =100 and 150ml from the ADS→ PO_2= 150

note: when you exhale you give the person the 150ml of fresh air in the ads that comes out first then another 350ml of the alveolar air so the composition will be (100mmhg*350+150mmhg*150)/500= 116mmhg o2. This air is known as **expired mixed air.**

Lung Volumes and Capacities

We have 4 volume and 4 capacities

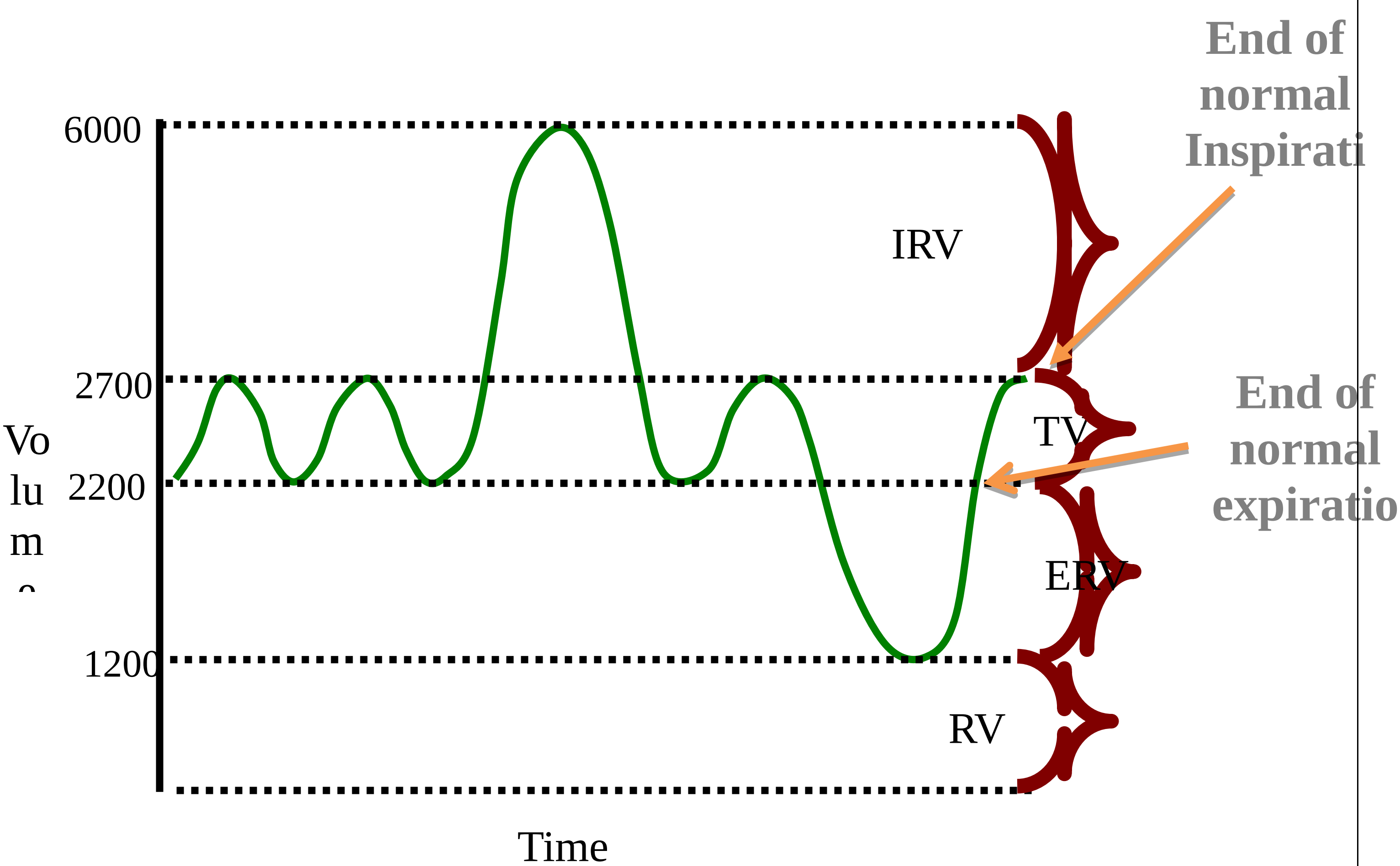
1) Lung Volumes

First you must know what are the definitions of :

1-Quite exhalation= muscle relax and the lung will pull the chest walls in so the air will go out.

2-Quite or normal inspiration = the chest wall will expands and the muscles will contract expanding the chest wall.

(Exhalation is passive and inhalation is active)



Remember we do not inhale into empty lungs.

The volume in the lungs before we inhale =2200ml
So at the end of inhalation the total volume = 2700ml (quite breathing)
The volume we inhale is called T.V(tidal volume)=500ml
T.V→ is the volume you inhale and exhale every time in normal breathing.

During exercise you can increase the inhaled air by extra effort
(More than normal)
In this case the extra air is called **I.R.V**(inspiratory reserved volume).
(the volume we can inhale extra to the T.V)

Note: in normal inhalation moving the diaphragm is enough
But if we want to increase the inhaled air like in exercise we use other muscles to help reaching the I.R.V.

Also we can increase air going out in exhalation (by extra effort=**active** exhalation)
And we call it **E.R.V**(expiratory reserved volume)

Now if you notice the lung is never totally empty the volume that never gets out of the lung called the **R.V**(residual volume)

If the the lung was totally empty from air, it will collapse and the walls of the alveoli will stick to each other's → and we will need a very high pressure to open it.

Capacities:

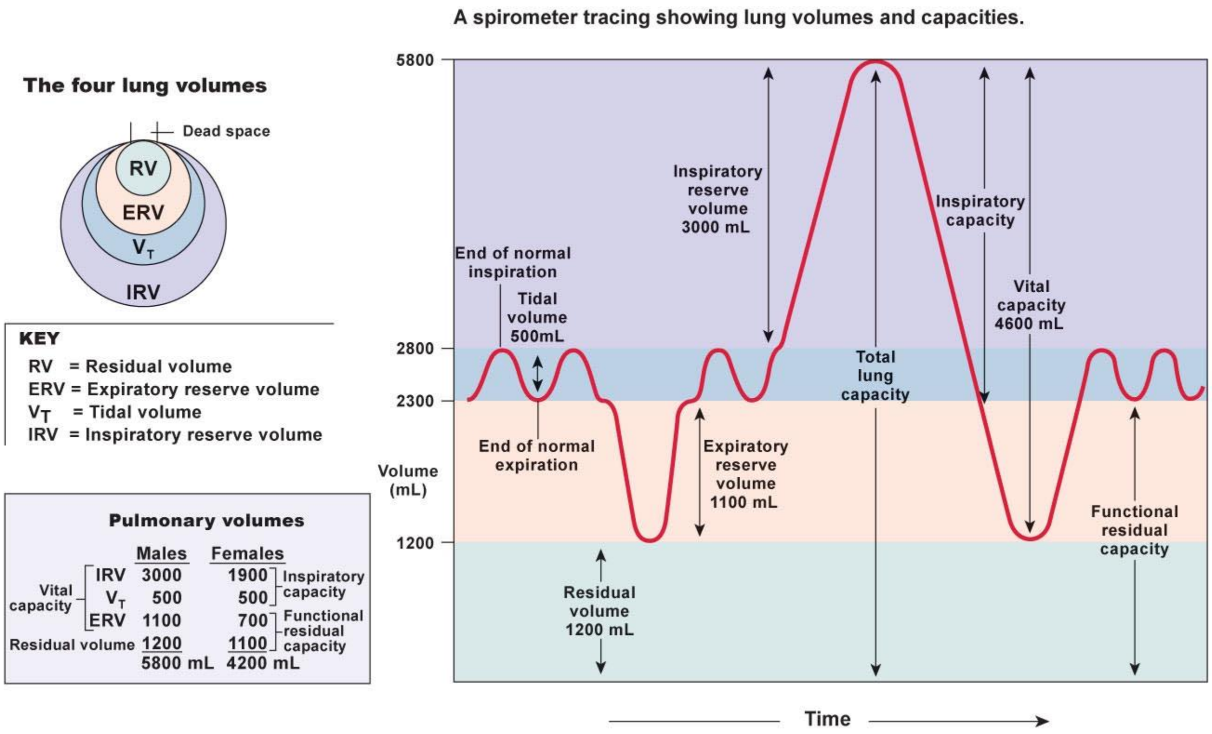
Lung capacity is the sum of two or more lung volumes

1- functional residual capacity (FRC): is the volume in the lung before we inhale the T.V

So it = E.R.V + R.V
F.R.C is the most important capacity.

2- Inspiratory capacity (I.C)= T.V+ I.R.V
3- Vital capacity (V.C)= the total air we can inhale after an active exhalation → so it = E.R.V+T.V+I.R.V
4- Total lung capacity (T.C) = the sum of all volumes (E.R.V+I.R.V+T.V+R.V)

Important: in normal breathing we only inhale and exhale the T.V so E.R.V and R.V will not go out.



Capacities are sums of 2 or more volumes.

ليس العجب فيمن هلك كيف هلك ولكن العجب فيمن نجا كيف نجا

Remember to always be yourself. Unless you suck

-joss whendon.