Doctor.021

no.

RS PHYSIOLOGY

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Corrector: laith

Doctor: yanal

writers' notes: green colour
doctor's notes: black colour
numbers are required
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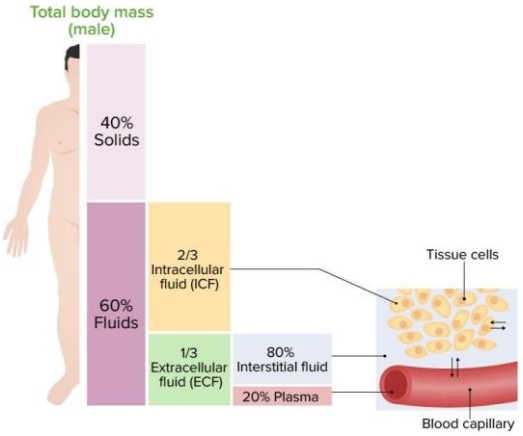
revision:

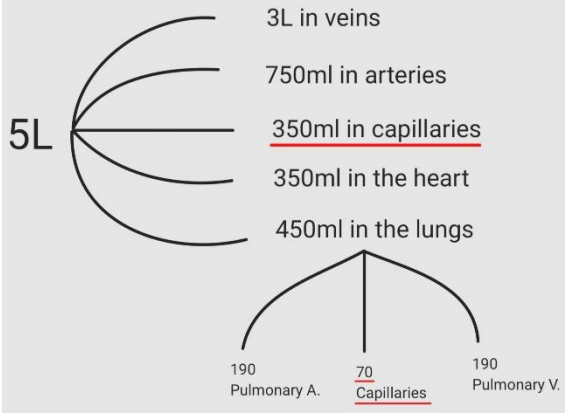
Flow=Driving force\Resistance, for O_2 the flow is diffusion, the driving force is change in pressure, and we will not use resistance we will use the permeability instead of resistance (permeability=conductance) and
Conductance=1/Resistance
Permeability depends on the membrane's properties which are surface area and thickness, and on the ion's properties (also called diffusion coefficient) which are the solubility and the square root of its molecular weight, so:
Conductance=(area of membrane/thickness)×(O_2 solubility/√O_2MW)

Body fluid compartments:

Let's say that we are talking about a 75kg man, so he will have 11L of fluid in his interstitium.

Blood volume=7% of total body weight, let' say we are talking about 75kg man, so we approximately have 5L of blood that will be distributed as follows:→ → → → →





introduction:

Doctor started the lecture explaining the importance of the respiratory system in the homeostasis of the O_2 as follows:
Progressive pulmonary diseases can lead to right heart failure.

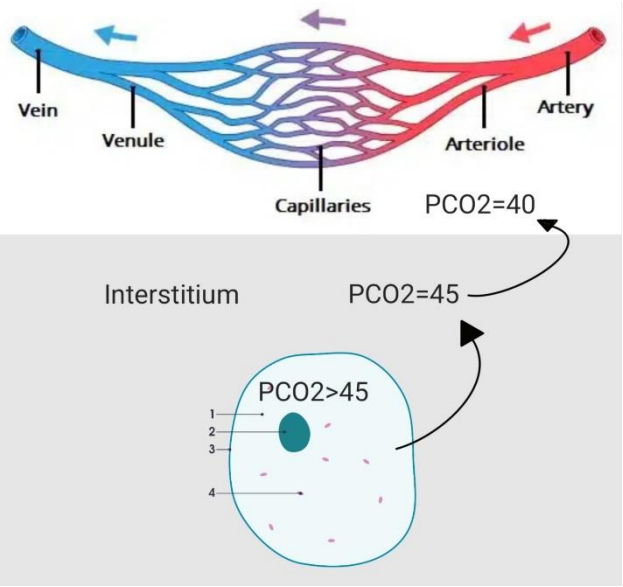
-homeostasis of O_2: O_2 can cross any biological membrane as the membrane doesn't exist (without the need of channels or carriers), even though, it has a limitation.

diffusion depends on the properties of the membrane such as thickness of the membrane and surface area, and on the property of the gas itself (is it O_2, CO_2, or N_2?) which depends on the solubility of the gas divided by the square root of the molecular weight of the gas, so the weakest participant in the diffusion is the molecular weight of the gas, WHY? **Because of the square root.**

if we have a pathological condition like pulmonary oedema, TB, pneumonia or fibroses, oxygen diffusion will decrease, and this is what we call respiratory distress syndrome type 1 (pO_2<50mmHg in arteries & pCO_2 is normal or low).
However this doesn't mean that CO_2 diffusion will be affected, when it is affected, it's called respiratory distress syndrome type 2 (pO_2<50mmHg in arteries & pCO_2>50).

the reason behind the fact that diffusion of CO_2 is affected after the diffusion of O_2 and is more dangerous is that the solubility (diffusion rate) is 20 times higher than that of O_2, and this makes sense that CO_2 is affected only in advanced stages and is worse.

Why does pCO_2 increase to more than 50mmHg in RDS type2?



Here, in the picture above is the normal condition:

While in RDS2 the pCO_2 coming to the capillary will be more than 40mmHg (let's say it is 41mmHg), as no good exchange happened in the lungs, and it will take more CO_2 from the cells, and return to the lung even higher, this loop will keep repeating and increasing pCO_2 in the blood, until at some point (the doctor said it'll take years) it will become more than 50mmHg.

O_2 diffusion is considered a <u>perfusion limited not a diffusion limited</u>, what does that mean?

Gases' Diffusion has two types:
1-perfusion limited gases: the pressure of these gases in the interstitium equilibrates with its pressure in the capillary so if you want to increase its diffusion you need to increase the perfusion of the blood (blood flow in the capillaries) so the diffusion is limited according to the blood perfusion.
2-diffusion limited gases: the pressure of these gases in the interstitium doesn't equilibrate with its pressure in the capillary regardless of the blood flow. One example is CO gas, when carbon monoxide diffuses across the alveolar membranes, it attaches to

haemoglobin. Almost none dissolves in the plasma, so its partial pressure in the blood can be considered zero.

Why oxygen is that important? oxygen is important because of its role in more production of more ATP in aerobic glycolysis compared to anaerobic.

Hypoxia:

Hypoxia is reduced O2 utilization by the cells, it has many causes: and this will be the main topic of our first part of the lecture:-

1st cause: no O2 in the air (high altitude): atmospheric pressure equals 760 mmHg at sea level, this pressure is caused by the air weight which comes from the gases in the air, (O2 percentage is 21%, N2 is 79% and CO2 is 0.04%.

in high altitudes, pressure decreases, but the percentages stay the same, at 5.5Km above sea level, pressure decreases to the half, 760/2=380mmhg and pO2 becomes 80mmhg.
at 11Km above sea level pressure decreases to one forth and so becomes 760/4=190mmhg and pO2 becomes 40mmhg.

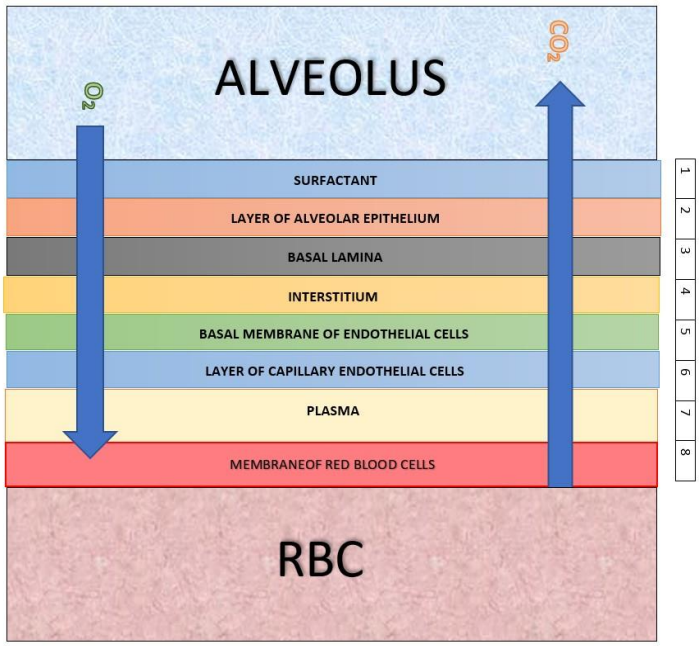
Based on the above, what do you predict the pressure to be at 2.75km above sea level?
it will be ¾ x 760=570

2nd cause: increasing the airway resistance, in case of: emphysema, chronic bronchitis, patent airway, non-stretchable lung (RDS: respiratory distress syndrome, lack of surfactant in the new born, fibrosis).
resistance is inversely proportional to the 4th power of the radius.

$$f = \frac{\Delta P r^4}{R}$$

3rd cause: respiratory membrane: (layers of respiratory membrane from inside to outside: 1-surfactant 2-alveolar epithelium 3-basement membrane 4-interstitium 5-basement membrane of the capillaries, 6-

endothelial cells of the capillaries. Thickness is between 0.2 to 0.6 micrometer.



4th cause: heart failure

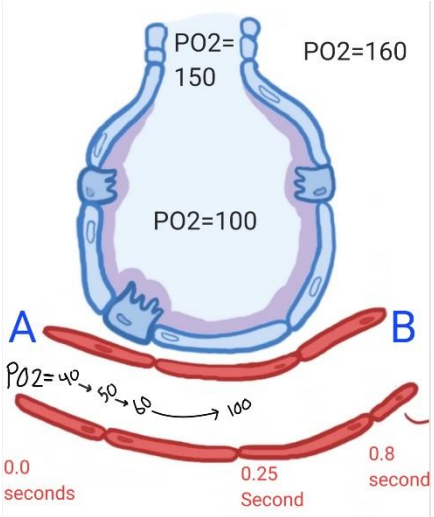
5th cause: anemia

6thcause: the cell itself is sick (septicaemia toxins that might poison the mitochondria, cyanide which can affect the electron transport chain).

7th cause: nerve conduction for respiration, we need the diaphragm which is a skeletal muscle and is innervated by motor neurons that come from the respiratory center in the brain and phrenic neurons or we can call them motor neurons in spinal cord, in polio for example it might affect the respiration and cause death, or even a disease that affect the medulla oblongata in the brain.

8th cause: diseases in the muscularity of the diaphragm as they are skeletal muscles.

Gases exchange in lung &systemic circulation:

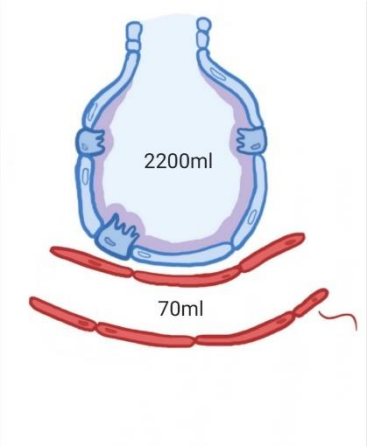


Picture (2-1)

Explaining the picture (2-1):
The doctor here asked: how much time do you think RBCs stays in the capillary (from A to B)?
Answer: it's the same duration of the cardiac cycle duration (0.8 second)
So let's say someone has a HR of 300 BPM, Cardiac cycle duration will be 60/300=0.2 meaning that it will take one RBC 0.2 second to cross from A to B which is not enough for the exchange.
So when the HR increases we will have 2 problems:
1. No enough time for the diastolic filling
2. The diastolic time is the time for coronary perfusion (perfusion occurs during diastole) so less perfusion.

The other thing Is that I only utilize one third of the respiratory membrane (the exchange only happened during the first third), look at picture (2-1) where pO_2 reaches 100mmhg only in the first third in a duration of 0.25, and no more exchange happening in the other 2 thirds) the other 2 thirds are kept preserved, so during exercise you might need these other 2 thirds and utilize them, this leads us to the conclusion that O_2 is not diffusion limited here.
Even though It might become diffusion limited in tachycardia for example, let's say the HR=300 so the whole duration from A to B will be 0.2 as we said before, which is not enough time for the full exchange (full exchange requires 0.25 second).

We started the journey by blood reaching point A with a pO2=40mmhg, then it is mixed with the blood in the lung as follows: (40+100)/2=100, but this doesn't make sense, shouldn't the answer be 70?! Why is it 100?

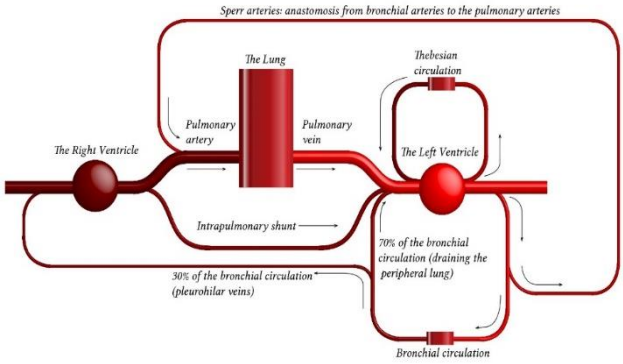


Because of the large volume difference, what will mostly happen is that the composition of the 70ml will become like the composition of the 2200ml, that's why PO2=100mmhg in the arteries and lung, ((100+40)\2=100mmhg)

And that's why the answer is 100mmhg.

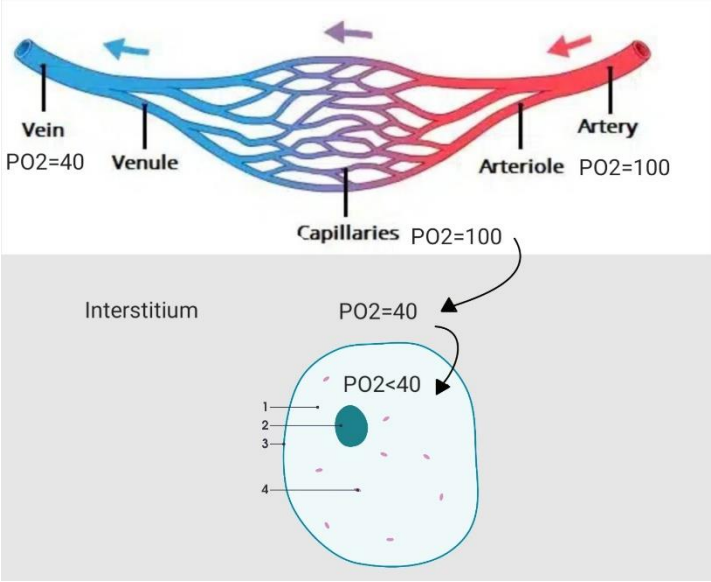
If pO2=100mmhg in the lung it should be equal or more than 95 in the arteries, meaning that:
(pO2A-pO2a)<5
But where did this 5mmHg difference came from? From the venous pollution.

There is some sort of pollution in the arterial blood, it's not pure oxygenated blood, because of the bronchial circulation which is defined as the bronchial flow to the intrapulmonary structures connects to the pulmonary circulation and drains through the pulmonary veins into the left atrium.



Because of this pollution of the blood, **<u>arterial blood has a pO2 equals to 95mmhg not 100mmhg, and so you will see the number 95 in the tables instead of 100 which is the true case.</u>**
If the difference is more than 5mmHg, this is an indication of a problem in the lung with the diffusion.

That was in the lung circulation, so what about the systemic circulation?



Here the volume of the interstitium is much larger than that of the capillaries (it's 11L in the interstitium and 350ml in the capillaries as we said before), so what will mostly happen is that the composition of the capillaries will become like that of the interstitium (O_2=40mmHg in both)

Now let's talk about some basic concepts.

1-the conductive zone of the respiratory airway: is the zone where is no gas exchange takes place, we can call it the anatomical dead space (ADS), there is a physiological dead space but we will talk about it later.

2-tidal volume: is somehow like the stroke volume in the CVS, so it's the amount of air you move through your lungs each time you inhale and exhale while you're at rest, which is normally equals 500mL, **150mL of them resides in the ADS (anatomical dead space).**

3-respiratory zone: is where gas exchange takes place, generally speaking it's the lung.

RMV (respiratory minute ventilation) = Vt (tidal volume) x RR (respiratory rate). 500mL x 12 = 6L/m

In the arterial blood, partial pressure of O_2=100 mmHg (its actually 95 but we will take it as 100 for now), pCO_2= 40 mmHg, pH= 7.4) and the goal of the respiratory is to achieve this. If Arterial blood gases (ABG) is normal, the lung is doing its job.
Any artery has the same property, however veins don't

You know that the general law of flow is flow=delta P/resistance, so assuming that the atmospheric pressure equals 0, (actually it is 760mmhg) then we have to manipulate the pressure inside the alveoli by reducing it to become less than the Patm, so it makes sense that if the resistance is too much then flow will decrease, and this is what actually happens in the case of emphysema, asthma and chronic bronchitis, and the problem is that you can't exhale.

Sometimes the lungs are fibrosed or in cases of RDS, the problem here is that you can't inhale.

We have several types of alveolar cells, bonder the picture bellow:

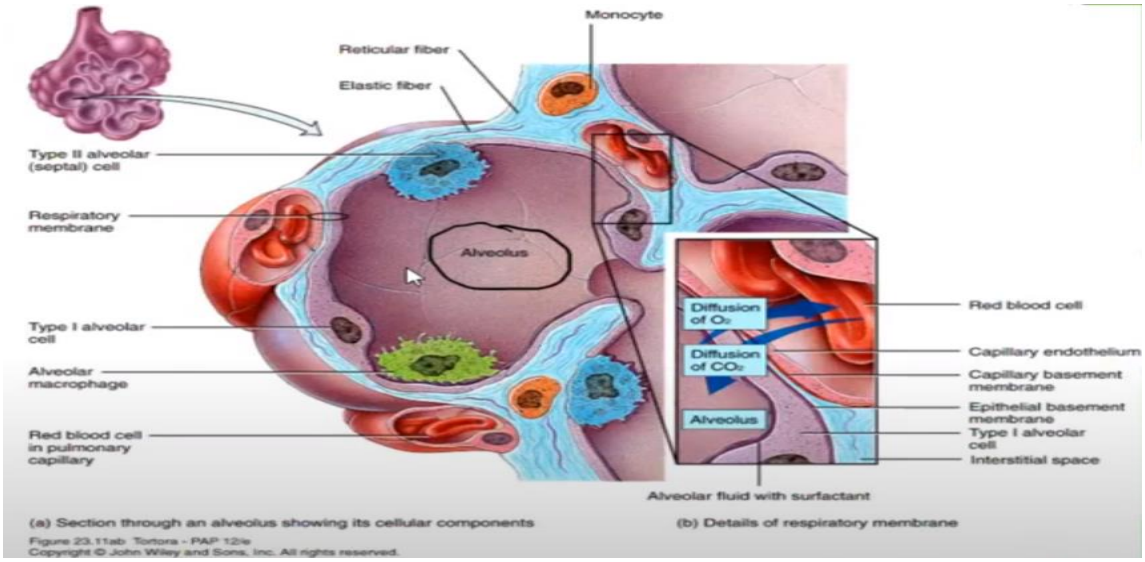


Figure 23.11ab Tortora - PAP 12/e
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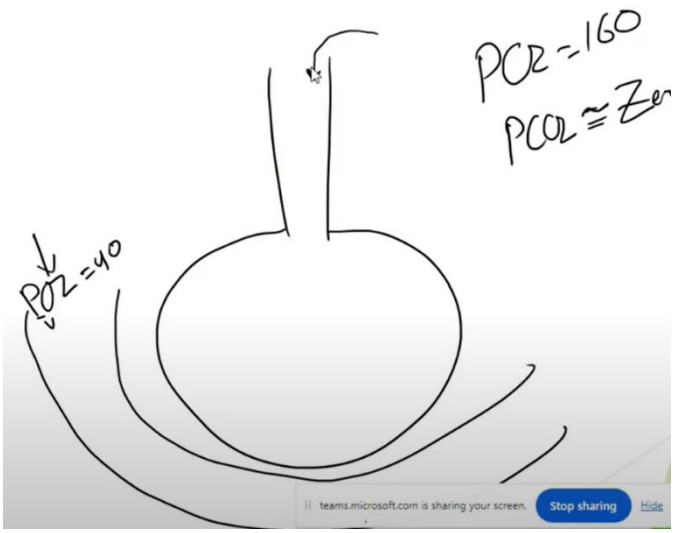
-type 1 alveolar cells are thin and they do the exchange job.
-type 2 alveolar cells are columnar and they produce the surfactant, (surfactant lines the alveoli to lower surface tension, thereby

preventing atelectasis during breathing).
-and we have the alveolar macrophages (dust cells).

Please pay attention here:
This is a **wonderful** drawing done by dr. yanal:



In the veins we have the pO2 equals to 40mmhg, and outside the body we have it equals 160mmhg which is 21% of the total air pressure, you know that Patm=760, once air enters the body it will be humidified, the pH_2O inside the ADS equals 47mmhg, by doing some math, you will have the total air pressure inside the body after being humidified without pH_2O as follows 760-47=713mmhg, what is the pO_2 inside the body? Its 21%x713= 150mmhg.

Now the pO2 in the alveoli is 100mmhg because of the diffusion of O2 into the capillaries. The composition of air inside the alveoli is:

40mmhg CO_2 (because of the diffusion from the capillaries to the alveoli), 100mmhg O2, and 47mmhg H2O, what do expect the pN_2 to be?

It's simple, 760-(100+47+40) = 553mmhg.
hmmm, too much numbers? I've told to pay attention.
the doctor said that you have to memorize the arterial pO_2 and pCO_2 only.

Moving to our next question: What would be the composition of air in the anatomical dead space in terms of pO_2 and pCO_2?

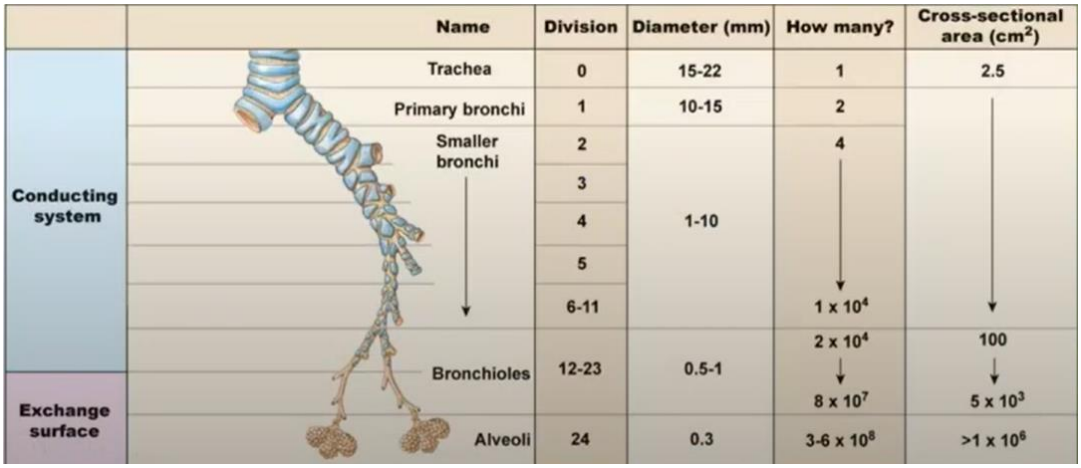
At the end of expiration, the composition of air in the ADS will be the same as in the alveolar, because it is coming from the alveoli.

Whereas during inspiration, 500mL of air inters the body, now the first 150mL of the total 500mL moves from the ADS into the alveoli, the doctor said: كإنك يا أبو زيد ما غزيت because the source of this 150mL of air is from the ADS which is from the alveolar after expiration, we call it the ADS ventilation. However, the rest 350mL of the air is what we call the alveolar ventilation and what the body truly benefits from, 350mL x12(RR)= **4.2L/m.**

Mixed expired air has a pO2 higher than venous and arterial pO2, that's why in case of CPR we give the patient mixed expired air, to illustrate that by a simple calculation, we do the following:

(ADS pO2: 150mmhg x 150mL + expired pO2 100mmhg x 350mL)/500mL= 116mmhg.

The doctor ended the lecture with this table:



	Name	Division	Diameter (mm)	How many?	Cross-sectional area (cm^2)
Conducting system	Trachea	0	15-22	1	2.5
	Primary bronchi	1	10-15	2	
	Smaller bronchi	2		4	
		3			
		4	1-10		
		5			
		6-11		1×10^4	
Exchange surface	Bronchioles	12-23	0.5-1	2×10^4 ↓ 8×10^7	100 ↓ 5×10^3
	Alveoli	24	0.3	$3\text{-}6 \times 10^8$	$>1 \times 10^6$

As you can see respiratory tract keeps dividing until 24 divisions, we divide the divisions into two categories, from 0-16 (we call the 16 division the terminal bronchiole) and from 17-24 (we call the 17 division the respiratory bronchiole and the 24 division the alveolus). This is one type of classification, another way of classification is to divide the division into two categories, the conducting system which is from 0-12 and it's covered with cartilage, and the exchange system from 13-24 with no cartilage.

Cartilage is a bony material and it makes the structure not collapsable, and as mentioned the divisions from 13-24 are not covered with cartilage and it can collapse which can lead to decreasing in the diameter, which will increase the resistance.

The end

لا تنسوا الدعاء لإخواننا في غزة وسوريا والسودان، وفقكم الله.