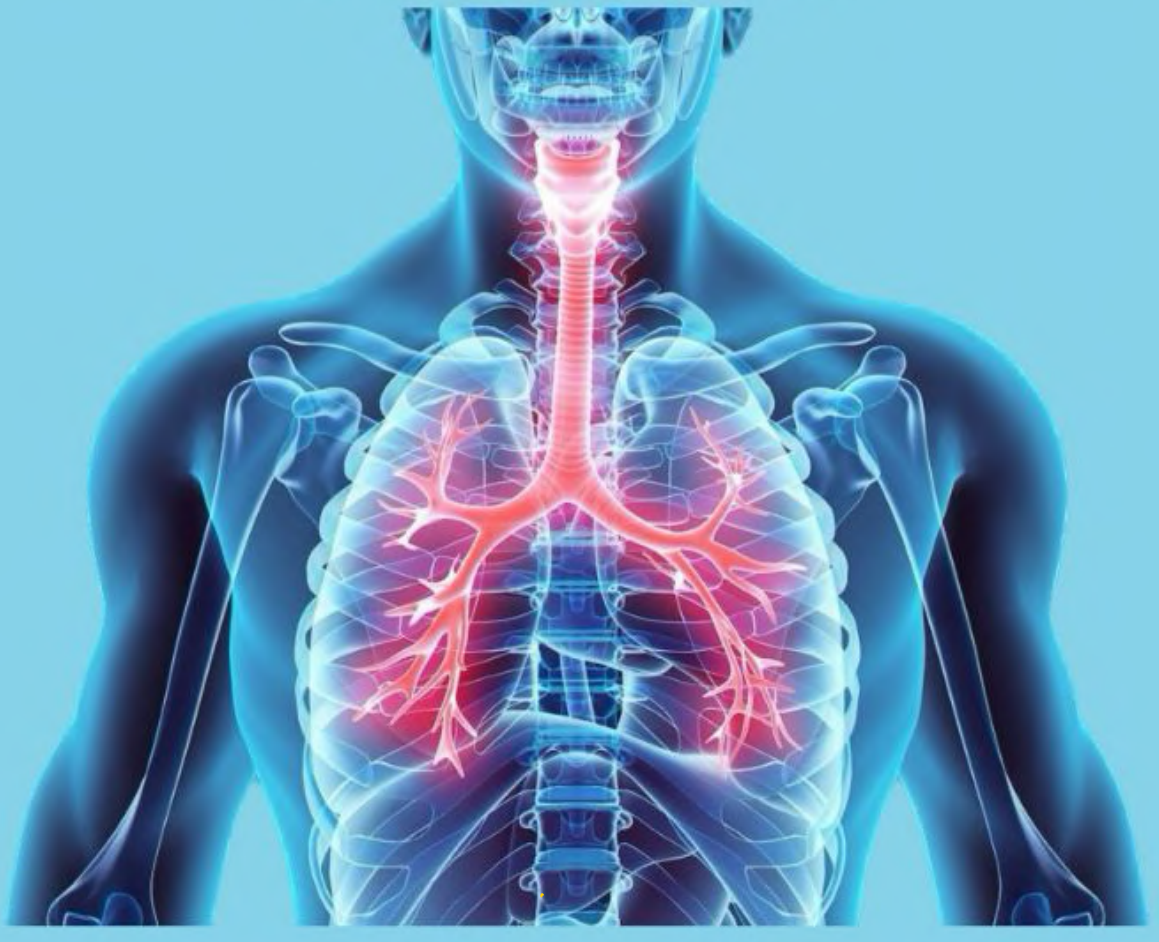
وَقُل رَّبِّ زِدْنِي عِلْمًا

النادي الطبي

RESPIRATORY SYSTEM

HAYAT BATCH

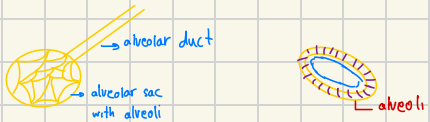


SUBJECT : Summary for physiology + test Q

LEC NO. : 2-6

DONE BY : Abdullah Bani Mustafa

To understand how breathing work we need to understand what type of tissues made up the lung, elastic tissue of the lung to tend to collapse the lung while the chest wall tend to move outwards which increase the thoracic cavity, also we need to understand what is the structure of alveoli, it's lined up with pseudo stratified epithelial cells with goblet cells and there is a fluid around them which make alveoli collapse due to the surface tension but due to a surfactant it wont collapse for the muscles the main one is the diaphragm which move downwards during inspiration increasing the vertical thoracic cavity so increasing in volume decrease the pressure of the pleural cavity making the air moves from the atmosphere to the lung making it bigger and making the pressure less during to increase in volume



So there is obstructive & restriclive disease which effect our ability to breath, so we diagnose it by calculating some lungs volumes by spirometer the volumes are-

1) Tidal volume: it is the volume of air inspired & expired during a normal breath cycle which is around 500ml, only the diaphragm is needed for the normal breathing cycle

2) inspiratory reserve volume it's the maximum volume of air that can be inspired above the tidal volume which is around 3000 ml

3) expiratory reserve volume it's the maximum volume of air that can forcefully expired below the tidal volume which is around 1100 – 1300 ml

4) residual volume it's the volume of air remain in the lung after forcefully expired which is around 1200 ml, which is used for oxygenate the blood in between breath cycles and prevent the lung from collapsing even if the lung collapsed there will be around 200 ml

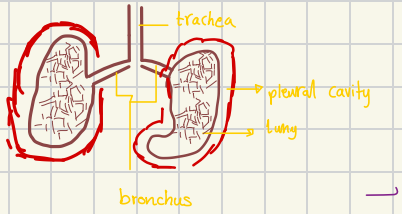
No we are going to talk about the capacities that we could calculate from the previous volumes which are

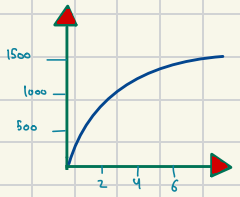
1) inspiratory capacity it's the total volume of air that can be inspired which is the sum of inspiratory tidal volume & inspiratory reserve volume which is 3500ml

2) functional residual capacity it's the total amount of air that remains in the lung after normal expiration which is the sum of expiratory reserve volume & residual volume

3) vital capacity it's the maximum amount of air that can be expired after firs filling the lung to the maximum extent so it's the sum of inspiratory reserve volume, expiratory reserve volume & the tidal volume

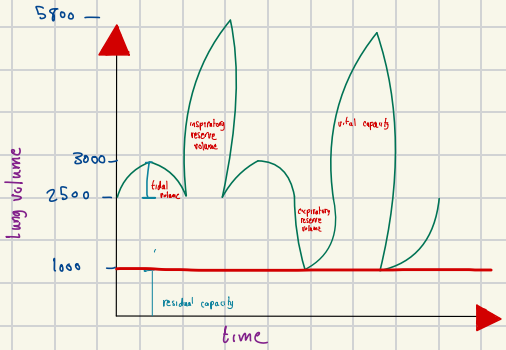
4) Lung capacity it's the maximum volume which the lung extent with air, which is the sum of inspiratory reserve volume, expiratory reserve volume, the tidal volume & the residual volume





this represent how lung volume change when patient force to inhale maximum amount of air

we need to understand that our lung elastic tissue tend to collapse so we have lung surfactant which prevent our lung from collapsing. The pleural cavity is very important to allow the air moving inside the lung because it creates negative pressure



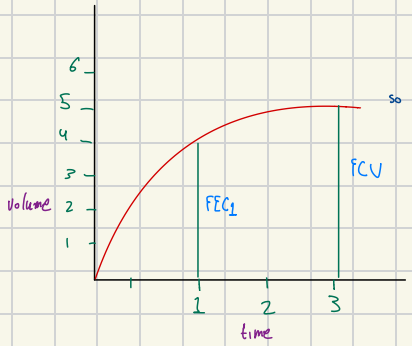
we need to know the pressures which allow the air to move in & out of the lung which are:

1) pleural pressure is the pressure of the fluid between the lung & chest wall which is negative due to chest wall & lung elastic tissue

2) alveolar pressure which is the pressure of the air inside the alveoli which is between 1 to -1 during breath cycle

3) transpulmonary pressure which is the difference between the alveolar pressure & pleural pressure which measure the elasticity

To diagnose more accurately we measure the forced vital capacity which represent the maximum volume of air can be forcefully exhale during rapid maneuver we can obtain FVC, FEV_1, FEF_{25-75}. we use a ratio to determine obstructive & restrictive disease this ratio is $FEV_1/FVC * 100\%$ which is usually around 80% is the normal result



so $\frac{FEC_1}{FVC} \times 100\%$

$\frac{4}{5} \times 100\% = 80\%$ ← Normal ratio

So if the ratio below 80% it's an obstructive lung disease such as chronic bronchitis, asthma & emphysema, while if it's an above 80% it's an restrictive lung diseases such as tuberculosis, Fibrosis and asbestosis exposure

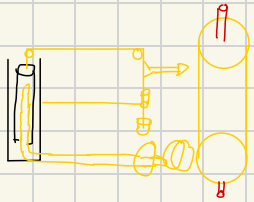
we made a test that can be done at home for early detection of only obstructive lung diseases, the test called Peak Expiratory Flow rate which measure the volume of air that forcefully expiried in one quick one exhalation which depend on sex, age & hight

Restrictive lung diseases interfere with inspiration which result decrease all the volumes & capacities such as in pneumonia, Tb, ARDS Pleurisy, diaphragm paralysis & pulmonary fibrosis, while obstructive lung diseases interfere with exhalation which increase FRC & RV while VC & FEV_1 FVC are reduced

The functional residual capacity is measured by helium dilution method, and also we can measure the new total air pass through the respiratory track by multiply tidal volume with respiratory rate

$$FRC = \left(\frac{C_{i,He}}{C_{i,F}} - 1\right) V_{i,spr}$$

$$VE = V_T \times F$$

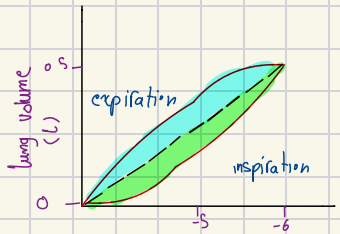


- now we are going to study lung compliance which represent the ability of the lung to stretch & expand, to allow the lung to expand so we should overcome the elasticity and surface tension which is caused by the fluid that lines the alveoli

$$\text{Lung compliance} = \frac{\Delta \text{ in Lung volume}}{\text{transpulmonary pressure}}$$

we can calculate the work by pressure & volume

$\frac{N}{m^2} \times m^3 = N\,m$ which is joule

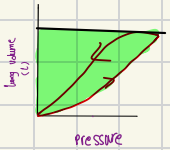


we can see that there is a difference between the inspiration & expiration curve this difference is called hysteresis

we can realize from the graph that at the beginning of inspiration it is harder than at the end of it due to surface tension → at first the molecules are so close to each other leading to increase in surface tension with time the distance will increase leading to decrease surface tension, while the opposite occur for expiration

so we can conclude the elasticity is inversely proportional with lung compliance. and note that in the absence of surface tension the two curves of inspiration & expiration would be the same & there will be no hysteresis

now we are going to see what changes occur on the curve in case of lung diseases

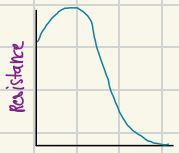


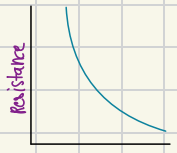
Restrictive diseases
eg Tb, silicosis & Fibrosis
it need more work to open the lung (noted by calculating the area under the curve)

obstructive diseases
eg emphysema asthma.
it need less work than restrictive disease (noted by calculating the area under the curve)

now we are going to talk about the air resistance inside the respiratory track, air resistance is the difference of pressure between the alveoli & mouth divided by air flow which is determine by the air flow velocity & air way diameter. The work for breathing is need for 20% of lung & chest wall tissues while 80% of airway resistance
- mostly carried by the air velocity instead of the track diameter
  - only 10-20% responsible for air resistance

so we can conclude that the highest air resistance is highest in the medium sized bronchus which is found around the 7th generation





No we are going to talk about the factors effecting the air way resistance 1) the diameter of the bronchus which is increased by A) increase the lung volume causing radial traction (increase diameter of the surrounding tissues such as bronchus) B) by stimulation of sympathetic adrenergic receptor B2 causing dilation & decrease in secretion of air way (so we can use B2 agonist for COPD treatment)
So increase in air way diameter leading to decrease in airway resistance and the diameter is decreased by A) decrease lung volume in expiration B) stimulation of parasympathetic cholinergic pos ganglionic fibers causing construction of the air way track C) stimulation of α receptors in trachea & large bronchi by irritants such as smoking induce bronchial smooth muscle contraction, so decrease the bronchial diameter lead to increase in air way resistance

Now we are going to talk about the lung surfactant which is mostly phospholipids with some proteins it's produced by type II cuboidal epithelial cells, it's responsible for reduce surface tension which increase the comphance & decreate the work needed for respiration it also prevent the lung from collapsing, and it prevent pulmonary edema by making interstitial fluid more negative thus reduce capillary filtration (movement of fluid out of the capillaries
Note that Young-Laplace's law state that " transpulmonary pressure depend on ① Radius ② surface tension

The lung surfactant is secreted in alveoli by 6th to 7th month & always present by gestational week 35, in premature babies of diabetic maternal the fetus is at great risk of respiratory distress syndrome causing atelectasis which is characterized by collapsing the lungs, edema within the lung cavity due to impairment in gas exchange & loss of lung surfactant, treatment include administration of exogenous surfactant with the use of mechanical respirators

now I'm going to study lecture (3)

1) alveolar ventelation ?
the rate of air flow that enter the exchange areas
= amount of the new air entering the respiratory area/minute

2) dead space:
space in the respiratory tracts where gas exchange does not occur also known as conducting zone

(A) anatomical dead space : it's the conducting zone which doesn't participate in gas exchange due to the thickness of their wall eg nose, pharynx & trachea
Functions of the conducting zone are:
1) warm the inspired air to the body temperature
2) adding H_2O vapor which slightly dilute the O_2 & N_2 which will decrease their pressure & concentration & it prevent the airway from drying out
3) removal of foreign bodies smaller than 2 microns

(B) total (physiological) dead space:
it's the anatomical dead place & the alveolar dead space (alveoli that doesn't get blood supply) in healthy individuals
usually = anatomical dead space 2 ml/kg so around 150 ml which increase with age or some diseases.

* the air in the dead space is the first air get expired which is around 150 ml → mostly O_2 & N_2 so this air could be used in CPR to provide O_2 to the patients in medical emergincies

calculate the volumes that enter the lung / minute in normal breath cycle

TV = 500 ml Frequency = 12-15/minute
500 x15 = 7500 ml / minute

anatomic dead space: 150 x15 = 2250 ml/minute
Alveolar ventilation: 350 x15 = 5250 ml/min

* pulmonary capillary volume = 70 ml
↳ the volume of the blood found in the capillary at any time
* pulmonary blood flow = 5000 ml/min

how to measure the volume of dead space (2)

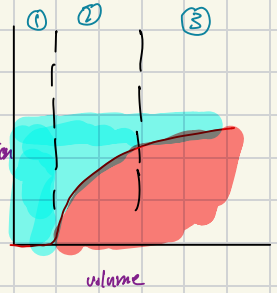
1) Bohrs method
depend on CO_2 partial pressure in the mixed expired gas

$$V_D = V_T * \left(1 - \frac{P_{ECO_2}}{P_{ACO_2}}\right)$$

P_{ECO_2}: partial pressure of CO_2 in the mixed expired gases
P_{ACO_2}: partial pressure of CO_2 in alveoli which = P_{O_2} in arterial blood

* this method measure volumes of the lung that doesn't eliminate CO_2, so it calculate the physiological dead space which include the alveolar dead space

2) Fowler's method
depend on the expired N_2, the perso inhale a pure O_2 100% oxygen, the expired fully, we measure the N_2 volume during expiration, so it is only measuring the anatomical dead space
the patien inhale 100% O_2 at the end of tidal expiration, then the patient expired the air through N_2 analyser



$$\frac{\text{blue area} \times V_E}{\text{Red area} + \text{blue area}}$$

① pure O_2 from the anatomical dead space which there is no N_2
② there will be N_2 which come from the alveolar gases because it participated in gas exchange
③ pure alveolar gas giving a constant graph

* Measurment of alveolar ventilation

$$V_A = f \cdot (V_T - V_D)$$
$V_A = 15(500-150) = 5250$ ml / min
increase in alveolar ventelation cause an $\uparrow O_2$ $\downarrow CO_2$ acedosis, $\downarrow V_A$ $\downarrow O_2$ $\uparrow CO_2$ alkelusis

in upright postion the ventelation / unit volume is greater in the loweresT part of the lung due to gravity effect on the lung while in supine postion all parts of the lung are equally ventelated.

lets explore the P_{ACO_2} & P_{AO_2}

1) P_{ACO_2} = 40 ± 4 mm Hg
this tension is inversly proportional with the alveolar ventilation so as result
1) hyperventilation → CO_2 ↓ → hypocapnia which will lead to respiratory alkalosis < 36 mmHg

2) hypoventilation → CO_2 ↑ → hypercapnia which will lead to respiratory acidosis > 45 mmHg

* Hyperpnea → result from increase metabolic CO_2 activity without increase in P_{ACO_2}

2) P_{AO_2} = 100 mm Hg

increase in alveolar ventilation cause increase in O_2 removal than the CO_2 is being added up,

P_{AO_2} is effected by:
- CO_2 partial pressure
- Changes in barometric pressure → ↑ altitude ↓ O_2
- fraction of O_2 inspired → in fire air ↑ CO_2 ↓ O_2

what are the circulation of the lungs?
there is 2 circulations in the lung 1) pulmonary 2) alveolar
the pulmonary circulation carries out all the cardiac output and responsible for gas exchang while the alveolar circulation only 1-2% of the circulation which carry the nutrients needed to the lungs.

1) pulmonary circulation:
pulmonary arter are thiner than systemic arteries around 1/3 of it, also they are wider which gives them the ability to be more compliance which will allow it to accommodate any increase in cardiac output & prevent the development of pulmonary edema, also there is a lot of lymph nodes drainage to remove any excess plasma protein to prevent pulmonary edema
pulmonary edema: the accumulation of fluid in the alveolar sacs, which prevent sufficient gas exchange leading to death
we need to know that the pulmonary circulation has lower pressure than systemic circulation because of the gravity → systemic need ↑ pressure to reach the brain which is above the heart.

Functions of the pulmonary circulations:
main → gas exchange
secondary
1) filters blood from thrombi & emboli then break it down by fibrolytics found within the endothelial lining of pulmonary blood vessels
2) metabolize vasoactive hormones such as angiotensin I to angiotensin II, inactivate NE, bardykinin, serotonin & prostaglandin E_1, E_2 $E_{2\alpha}$

4) blood reservior as 10% of the total circulation blood volume is in the pulmonary circulation

5) many WBCs also can secreate immunoglobins such as IgA, bronchial mucus to contribute to its defense against infection

Pressure of the pulmonary circulation

when the RV contract it push the blood at around 25 mmHg reaching the pulmonary artery it decreases along the artery to around 12 before entering pulmonary capillaries, in the capilaries the pressure is around 8 then in the vein it's down to about 0(-5 mmHg) when reaching the LA any further increase result a pulmonary edema which is fatal.

how to measure the LA pressure?
by pulmonary wedge pressure, which is basically puting a catheter to the RV up to the pulmonary artery, the catheter contain an inflated balloon with a tip, the catheter can reach before the pulmonary capillaries & read the pressure their wich is around +2 higher than the LA

Now we are going to study the resistance of the pulmonary circulation which are carried by 2 factors

1) the walls of arteries & arterioles such as in the systemic circulation

2) the lung volume which effect the capillaries effecting the resistance (only in PC not in SC)

why are the capillaries effect resistance in PC but not in SC?

because their structure is different than in SC how?

they are 2 sheets above each other connected to each other so it would accommodate all cardic output. so it makes them able to be compressed when the alveolar pressure exceed the capillaries pressure

when the cardiac output increase it won't lead to increase in pressure that is due to

1) capillary recruitment → in normall not all capillaries are being perfused, when cardiac output increase they will recruit those closed ones

2) capillary distenation → increase the space between the two sheets of the capillaries making more room

* the previous two process will allow to reduce the resistance of the blood flow so it could accomodate the increase in cardiac output

2) walls of the BV

they are effected by the lung volume, when the lung volume increase it pull the BV with it increasing its diameter leading to a decrease in blood resistance, while decreasing the lungs volume compress the BV leading to increase the pulmonary resistance

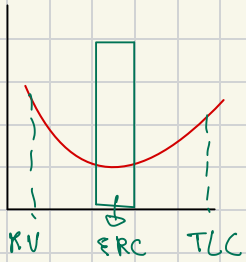
the vasoconstriction are

1) hypoxia
2) serotonine
3) NE
4) histamine
5) Thromboxane A2
6) leukotriens

the vasodilater

1) NO
2) Ca^{+2} channels blockers
3) adenosine
4) Ach
5) PGI_2
6) Isoproterenol

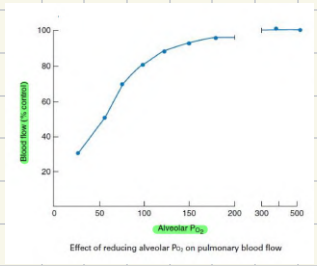
when lung expand the alveolar vessels are compressed while the extra alveolar vessels are distind → resistance, whe lung decrease in volume, alveolar vessels dislind while extra alveolar vessels are compressed creating high resistance so according to this the pulmonary resistance curve will be like the U letter, lowest resistance at the functional residual capacity



now lets discover what is the differance between hypoxia & hypoxemia

1) hypoxia : it's a result of decreasing the O_2 in the alveoli which lead to decrease in NO concentration which increase Ca^{+2} concentration causing vasoconctriction which will eventually will cause hypoxemia

2) hypoxemia : it's decreasing the O_2 content in the blood for different causes such as anemia

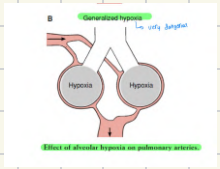


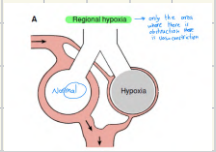
Effect of reducing alveolar P_{O_2} on pulmonary blood flow

there is two type of hypoxia that occur in our body

1) Regional hypoxia: cause vasoconstriction in the poorly ventelated are in order to drive the blood away from it

2) Generalized hypoxia :- vasoconstriction occur in both lungs causing increase in pulmonary artery pressure causing Rt. ventrical hypertrophy





* left heart heart failure, mitral stenosis can cause increase in LA pressure if above 7 it will cause pulmonary edema

now we are going to talk about the blood flow in the lungs & which factors play role in it

1) alveolar oxygenation:
↓ oxygenation → vasoconstriction
→ automatic redistribution of blood flow to well oxygenated areas

hydrostatic pressure:
the pressure calculated by the force of the pumped air - the vertical weight of the blood
↳ so highest point at the lowest part of the lung, and the lowest point at the highest part of the lung, increase in pressure lead to increase in blood flow because it can generate enough force to open the capillary

This will creat 3 zones
zone 1 :- $P_A > P_a$ so no blood flow
zone 2 :- $P_a > P_A > P_v$ intermittent blood flow
zone 3 : $P_a > P_v > P_A$ so continuous blood flow

in healthy individuals there is no zone 1, above the heart 10cm we find zone 2 and the rest of the lung is zone 3, during excercise even zone 2 become zone 3
zone 1 might occur when pulmonary pressure is low such as hypovolemic shock or pulmonary emplism or when a person exhale so strongly making the pressure above 2

The dynamics of capillary fluid exchange

① lower hydrostatic pressure, this decrease the amount of fluid outside the vessel
② higher negativity in interstitial fluid so it could take the fluid from alveoli to the interstitial fluid
③ the capillaries are more leaky to the proteins allowing them to pass through
④ the surface tension tend to take fluid to the alveoli
⑤ the ↑ alveoli pressure pulls air outwards

Filtration pressures

1) capillary hydrostatic	7 mm Hg
2) interstitial colloidal	14 mm Hg
3) interstitial hydrostatic	7 mm Hg
	= 29 mm Hg

absorption pressure

plasma colloidal pressure : 28 mm Hg
* the extra 1 is absorped by the lymphatic system and we found them more at the terminal bronchioles

Pulmonary edema could be caused by
1) cardiogenic reasons such as left heart failure cause increase in LV pressure → ↑ hydrostatic pressure
2) non cardiogenic reason such as pneumonia, ↑ surface tension eg ↓RDS causing damage to capillaries → leaking proteins → ↑ extravascular colloidal pressure

physics law of gas diffusion x gas partial pressure

1) in respiratory track gases are transported by simple diffusion so gas move from the high concentration to the low concentration area
→ explain why alveolar P_{O_2} = arterial P_{O_2}
↳ symbol used to describe partial pressure

2) Henry's law suggest that the higher the ability of gas to dissolve the less it would add partial pressure within solution

$$\text{partial pressure} = \frac{\text{concentration of gas}}{\text{solubility coefficient}}$$

3) the direction of diffusion is determined by the difference of pressure between the wall of the alveoli
O_2 higher in alveoli 100 ↑ Go gradient
O_2 less in vessels : 40
CO_2 less in alveoli 40 ↓ G gradient
CO_2 higher in vessels 46

4) the vapor in alveolar gas is 47 mmHg

5) Fick's law which suggest that the diffusion rate is

Ⓐ directly proportional with
1) sectional area
2) partial pressure of the gas
3) solubility of the gas
4) temperature

Ⓑ inversly proportional
1) distance (thickness of the wall)
2) $\sqrt{\text{molecular weigh of the gas}}$

$$\text{Diffusion rate} = \frac{\Delta P \times A \times S}{dx \sqrt{mw}}$$

we can conclude that CO_2 is 20 times faster in diffusion due to its high solubility coefficient

* important numbers
P_{AO_2} = 100 mmHg
P_{AO_2} = 46 mmHg

	* Atmosphere	humidified	* alveolar	expired
N_2	597	563	563	566
O_2	159	149	104	120
CO_2	0.3	0.3	40	27
H_2O	3.7	47	47	47

* O_2 absorption rate at rest 250 ml/min
* O_2 absorption rate at excercise 1000 ml/min
* CO_2 production rate 200 ml/min
* CO_2 production rate 800 ml/min
if the rate of O_2 & CO_2 is different during excercise how the P is still constant?
increase alveolar ventilation 4 times

how does the diffusion rate increase at excercise while all of the factors are constant?

what actually changed is the blood flow, at rest the RBCs spend 0.75s in the capillary until they are out, but they only need 0.25s to be oxygenated so during excercise the RBCs will only spend 0.25s in the capillary resulting more blood flow so the O_2 is being diffused faster

O_2 at resting → diffusion capacity = 21 ml/min/mmHg
increased in excercise

CO_2 at rest 400 – 450 ml/min/mmHg
1200 – 1300 ml/min/mmHg

TEST QUESTION:

Q. Concerning the airways of the human lung:

A. The volume of the conducting zone is about 50 ml. No 150ml

B. The volume of the lung at the end of quite expiration is about 5 liters. No 2.5 – 3 L

C. A respiratory bronchiole can be distinguished from a terminal bronchiole because the latter has alveoli in its walls. opposite the respiratory bronchioles has alveoli on its wall

D. On the average, there are about three branchings (i.e. generations) of the conducting airways before the first alveoli appear in their walls. No 16

E. In the alveolar ducts, the predominant mode of gas flow is laminar rather than turbulent. true due to the large surface area

Test Question:

Q. A 48-year-old patient undergoes a pulmonary function test. At which lung volume would his pleural pressure be most negative? the pressure is more negative when the lung at maximum volume because volume is inversely proportional with pressure

A. Residual volume. 1200 ml

B. Functional residual capacity. 2300 ml

C. End of tidal volume. 500 ml

D. Total lung capacity. 5800 ml

E. Middle of forced vital capacity. 2000 ml

Test Question:

Q. Pulmonary surfactant:

A. Increases the surface tension of the alveolar lining liquid. no it does the opposite

B. Is secreted by type I alveolar epithelial cells. type II

C. Is a protein. no phospholipids

D. Increases the work required to expand the lung. decrease

E. Helps to prevent transudation of fluid from the capillaries into the alveolar spaces. true

Test Question:

Respiratory dead space:

A. Saturates inspired air with water vapor before it reaches the alveoli. True

B. Removes all particles from inspired air before it reaches the alveoli. false particales less than 2 microns can pass

C. Decreases when blood catecholamine levels rise. False, it dilate the zone so increase it

D. Decreases during a deep inspiration. false increase in inspiration & decrease in expiration

E. Increases during a cough. False because it contract making it smaller

Test Question 2

Which is a feature of high altitude pulmonary edema? → generalized hypoxia

A. Associated with low cardiac output. No → increase cardiac output

B. Associated with pulmonary hypertension. ✓

C. Occurs only in unacclimatized persons. ✗ both

D. Exercise has no effect. false → adaptation

E. Associated with increased left atrial pressure. ↳ Not related

Concerning the extra-alveolar vessels of the lung:

A. Tension in the surrounding alveolar walls tends to narrow them. ✗ No wider them

B. Their walls contain smooth muscle and elastic tissue. ✓

C. They are exposed to alveolar pressure. capillaries not arteries ✗ Lung volume

D. Their constriction in response to alveolar hypoxia mainly takes place in the veins. ✗ No arteries

E. Their caliber is reduced by lung inflation. ✗ No increased

Test Question:

Q. Concerning the diffusing capacity of the lung:

A. It is best measured with carbon monoxide because this gas diffuses very slowly across the blood-gas barrier. not the barrier its low solubility

B. Diffusion limitation of oxygen transfer during exercise is more likely to occur at sea level than at high altitude. No the oppisite

C. Breathing oxygen reduces the measured diffusing capacity for carbon monoxide compared with air breathing. yes, because O_2 & CO bind to Hb

D. It is decreased by exercise. No increased

E. It is increased in pulmonary fibrosis, which thickens the blood-gas barrier. Not at all