Animal Physiology
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Module - 01
Lecture – 28

Welcome back, so we are in to the Animal Physiology course of the NPTEL. So, today we will be starting, the aspect of respiration, where basically the gaseous exchange taking place, we take the air from there the oxygen is being absorbed by the blood vessels, and deoxygenated blood, which is rich in carbon dioxide is being thrown out of the body. So, this whole process takes place, in the lungs and this whole mechanism by which, these gaseous exchange is taking place falls under the process of respiration. And one of the driving forces of respiration is the partial pressure of the different gases, which are present in the air, so let us start it, this is our section 7 and it is respiration.

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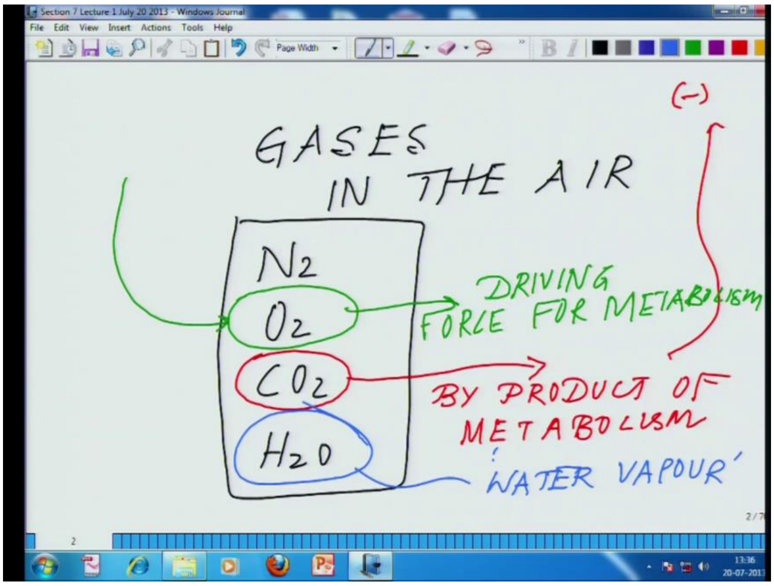

So, before we get into respiration, let us see what are the different gases present in the air, gases in the air one of the major percentages is on nitrogen, you have oxygen, you have carbon dioxide and you have water vapor and few other gases in the air. And the our major concerns are with two gases one of them is carbon dioxide, which is the byproduct of all the metabolism, by product of metabolism, which needs to be got rid of this has to be rejected from the body. And since we live in oxygenated environment in oxygen world, so oxygen is the driving force for metabolism.

So, these are the two gases, which is our major concern along with significant presence of water vapor, because this is the medium, where these gases absorbed or kind of mix with each other. So, essentially what is happening in this whole process, essentially what is happening in this process, let us divide this process into two different parts part one, the heart is receiving all the impure blood, which is completely laden with carbon dioxide.

And these, carbon dioxide rich blood is being sent to the lungs, where those blood vessels, throw away the carbon dioxide and picks of the oxygenated blood, and through pulmonary vein, the only vein which brings pure blood comes back to the heart and is being pumped. So, there is a small circuit, which is called pulmonary circulation, then there is a phase two, which is responsible for this process to take place is we are inhaling the air and from the air, the process by which carbon dioxide is being thrown out, and oxygen is taken in, so if I had to put in diagrammatic manner, then this is how it look like.

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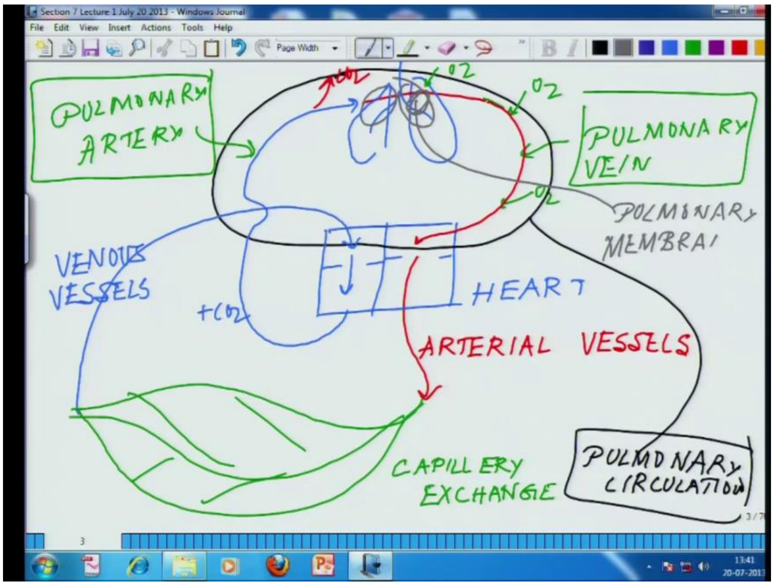

So, this is heart out here, the four chambers with a connection left and right, so here all the impure bloods are coming in it moves to the lower chamber, so this is our heart. And from here, this is impure blood which is rich in carbon dioxide, plus Co2 blood goes to lungs, these are the two lungs in the lungs, it gets rid of carbon dioxide and in the mean time it picks up oxygen and then oxygen rich blood.

Now, comes back here from here it is being sent all over the body, and these are the arterial vessels, this is just a recap what we have done in the heart and the circulation, and these are the venous vessels. And here, you have the area of the huge network of capillary exchange, this is the zone of capillary exchange and this one is called, this vessel is called pulmonary vein, which is carrying oxygen rich blood all over the place and this one is called pulmonary artery.

So, this is pretty much, is the layout of the system and this part, this part of the circuit is called pulmonary circulation. So, then the important part here, is the zone where this exchange is taking place and this is exceptionally important to understand, where this exchange is taking place and how it is taking place. So, moving on to this basically, it has been observed at that the exchange zone is also called as the pulmonary membrane, if I go back to this, this zone, where this exchange is taking place this is called pulmonary membrane.

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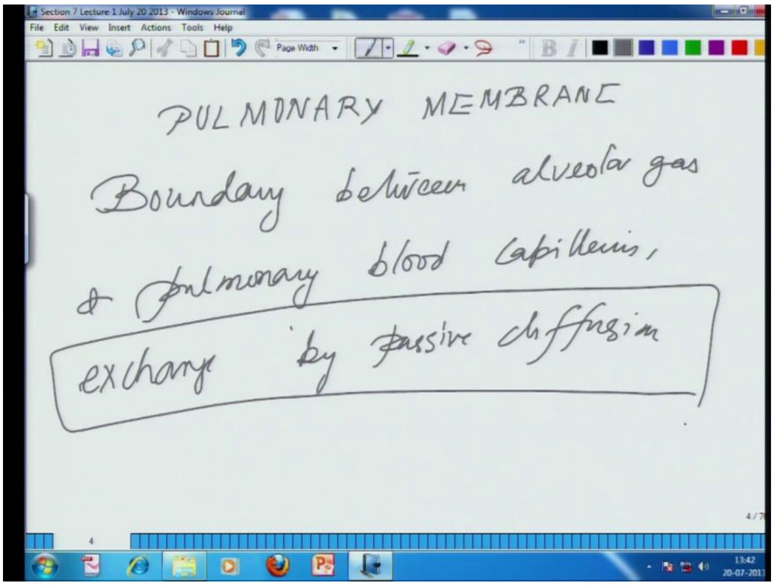

Now, at the pulmonary membrane, pulmonary membrane can be as such defined as, the boundary between the alveolar gas and pulmonary capillary, pulmonary membrane is the boundary between the alveolar gas and pulmonary blood capillaries. And, the exchange is taking place by passive diffusion this is simple diffusion process, which is taking place. So, what exactly happens essentially is at the pulmonary vein, at the pulmonary membrane.

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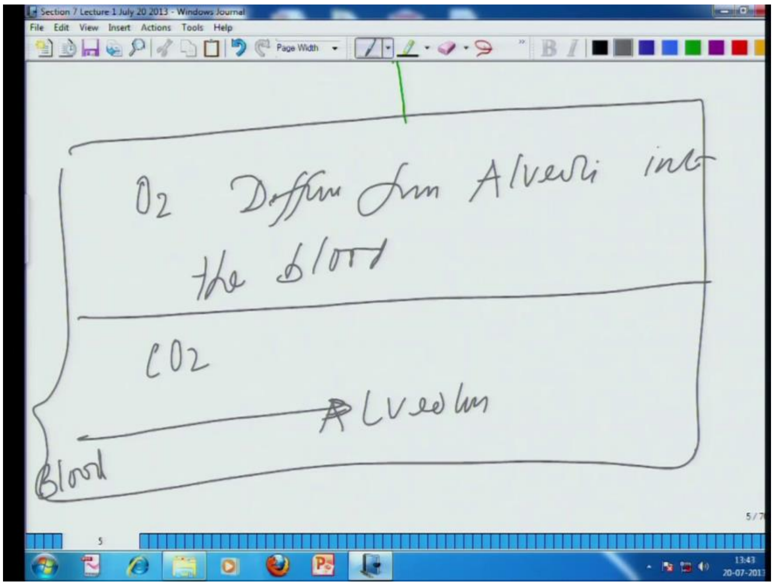

Oxygen diffuse from alveoli into the blood step one, where as Co2 from the blood moves on to the alveolus, though I have not defined what is alveolus and what is the structure, now so next what I will do, I will define this structure.

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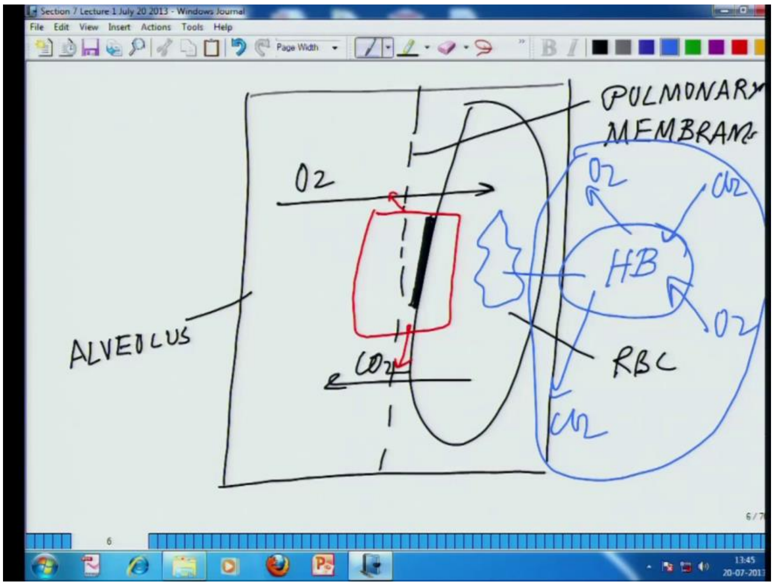

So, other word, the way if you, diagrammatically or graphically if you show it, this is how it looks like, graphical representation looks something like this, if this is the pulmonary membrane, it is a membrane with the this is the pulmonary membrane. And, from this side the oxygen, this side so this is basically, the alveolus and these are the RBC's, Red Blood Cells. So, the red blood cells picks up the oxygen, from the alveolus, whereas, throw away the carbon dioxide, along the pulmonary membrane.

So, if you see there are two membranes here, one is the membrane of the red blood cell out here, which I am darkening up and then you have the pulmonary membrane. So, essentially what is happening, the RBC's, which are rich in, so basically the RBC's, which are exchanging the gas, not the other blood component, there are WBC's is on blood ((Refer Time: 10:11)) and they are not involved in, any kind of oxygen exchange.

And, specifically in the RBC's, what we will be covering is that, there is a molecule called the hemoglobin, which is essentially is the molecule which binds to the oxygen, and distribute it all over the body, and vice versa. It binds to the carbon dioxide, and brings it back and throw, the carbon dioxide from its body and picks up the oxygen, so what essentially we will do, we will study the two levels, the level out here, why this exchange is taking place at the alveolar membrane.

And level two is out here, how this I am just putting the short form of Hemoglobin H B, how the hemoglobin is actually, binding to Co2 or O2 and how it is getting rid of O2 and how it is getting rid Co2. This whole dynamics by which, this hemoglobin molecule works we will be studying in the part two if this particular chapter, so now what I will do, I will give you the gross anatomy that will help you to understand, how this whole structure works, in order to understand the gross anatomy it is very easy if you look at yourself.

So, we inhale the air through our nose like this, that air, which we inhale passes through the trachea, there is a vessel called trachea. The trachea take sit to the two lungs which are present here, which are basically the one which is involved in all the exchange of gases, at some point rather you must have at least seen this picture.

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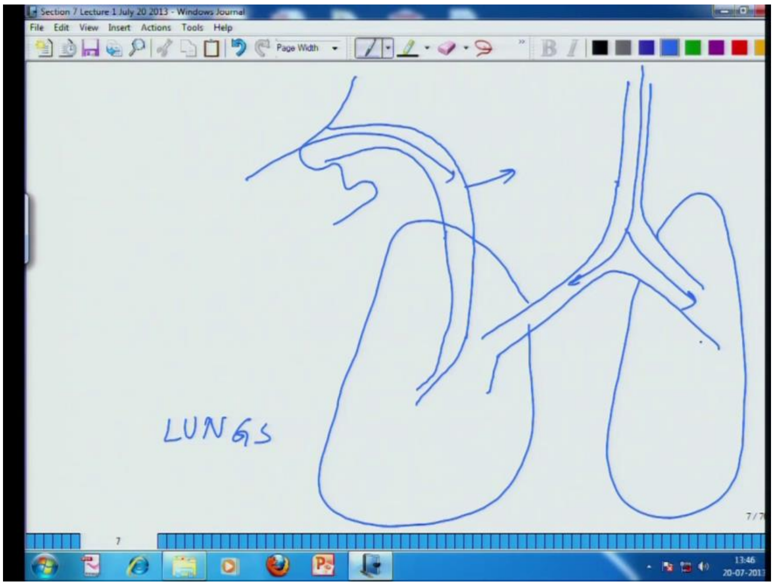

So this is the nose, so here is the trachea moving through, and this trachea eventually, essentially split up, so if I show the frontal view now. So, if the trachea in the front this, is the side view I am showing, so the frontal view wise like this, this trachea split up into two, then there are multiple splitting we will come to that and here is the organ called lungs. And we have two lungs, left and the right lungs, so air is moving like this, or air is moving along this, and getting split up. So, now what we will do, we will look in depth how this structure really looks like, save it.

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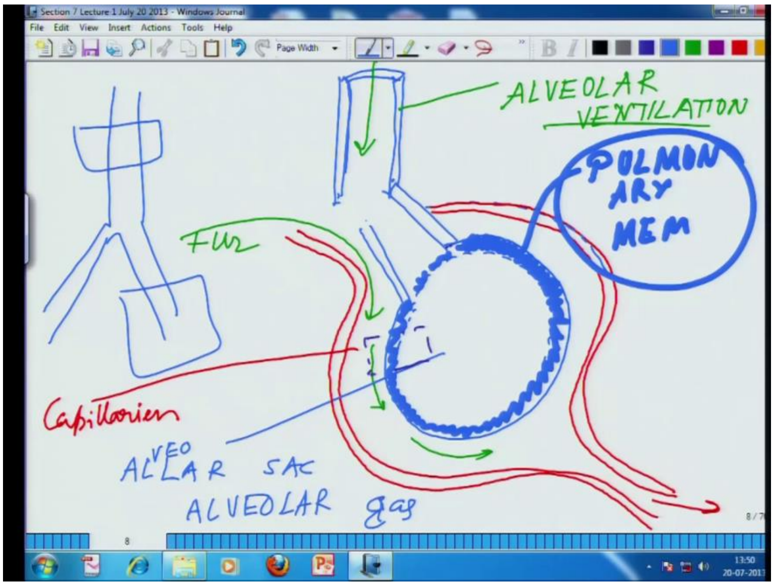

So, if you look at the cross section of this say for example, this tube what I have just now drawn for you if you cut this over it here, or somewhere out here you cut it take a cross section of it. So, the cross section looks something like this, so this is the cross section, I am now drawing, so I will just draw one side of this vessel, that is good enough for one second. So, this is the ((Refer Time: 13:21)) here you have, something like this membrane like structure and inside this you have another membrane sack and, which is surrounded by, this is the blood vessel which is coming in close proximity to it.

So, the red color what you see is the blood vessel double membranous, so I am not drawing the this side I am just showing you one magnified view of it. So, this is where, the alveolar ventilation is taking place which is nothing but, exchange of oxygen and carbon dioxide, alveolar ventilation is taking place ventilation and what is happening here, is here the venous blood coming, or, or you can call it like you know, the arterial blood which is coming, which is plus Co2 blood which is reaching out here in the proximity of the alveolus.

The alveoli is basically, so this is structure, what you see is that called alveolar sack or containing alveolar gas. And, here you have the capillaries and here are the blood flowing through and so here the blood comes and exchange is taking place, which I am highlighting now this is the zone, where this exchange is taking place. Now, I talk about, how this exchange is taking place and this is essentially, this membranous structure what you see, what I am going to highlight now is this is the pulmonary membranous structure, which is actually responsible, this is pulmonary membrane.

This is the one, which will be talking about why and how this structure is involved in any kind of exchange of gases. Couple of things, which I expect you people to go back to the very basics of class eight or nine, Dalton's law of partial pressure, this is very anyway I will be covering, but you can just go through it that will help you to understand. So, the whole idea, before I even go to the nitty gritty details of it, the basic idea of the gaseous exchange is very straight forward always remember this logic.

If the partial pressure of a say gas x is higher at one point and lower at another point, say gas x, so what will happen is that, where this gas is at higher partial pressure will move to the zone of lower partial pressure by simple potential drop. This is the simplest logic, by which you can understand the whole gaseous exchange phenomenon, so in other word if I said this, now recollect, what I am trying to tell you this is a situation. Where the impure blood or the carbon dioxide rich blood, which is coming to the lungs has to throw away the carbon dioxide from the blood, to the outside the body and that thing will take place, through the alveolar ventilation passage.

So, essentially, that means, the partial pressure of carbon dioxide, inside the impure blood vessel should be higher than the partial pressure of the alveolus, where the exchange is taking place. Then only it is possible, the carbon dioxide will move from a higher partial pressure to a lower partial pressure and vice versa in the case of oxygen, because these RBC's will have to pick up the oxygen.

That is only possible, when the partial pressure of oxygen inside the alveoli, is much higher compared to the partial pressure of the RBC's of oxygen and from the higher partial pressure, they will move to the lower partial pressure this is the basic, basic, basic fundamental thumb rule, which you have to remember. As long as, this fundamental one, because this whole thing revolves around partial pressure, as long as this simple concept of partial pressure is clear to you rest is all cake walk, rest is all kind of you know, technical details you are filing it to understand.

But, this whole governing dynamics of this whole gaseous exchange, revolves around it is partial pressure and solubility, and I will be anyway writing this, just give you in flare. So that, so just summarize what we have done, we talked about the nose from the nose you inhale, then there is a trachea, trachea bifurcates into two parts, like this and one for the left lungs, another for the right lungs.

Inside the lungs, we have much more further distribution eventually, they form they end up with forming a big sack like structure, which is called the alveolus, which are in close proximity of the blood capillaries, or the blood vessels, which are entering the lungs to oxygenate the blood. So, this is the overall, I should say the anatomy and the visual picture, which you people need to get in your mind and as I told you, this whole thing is governed, governing part of the this is structural part of it, the functionality is being determined by the simple thumb rule of partial pressure.

These two concepts have a picture in your mind, you are inhaling it through the trachea, trachea bifurcates into several distributaries and at the end it forms almost around one micron thick membrane, which is alveolar pulmonary membrane or alveolar membrane what, so ever you call that, whichever you call that. It is a very, huge surface of gaseous exchange and they are in close proximity with the blood vessels and from the blood vessels, within the blood vessels. You have these RBC's, which throws away, the carbon dioxide and picks up the oxygen, and that is all taking place in the alveoli and that is, because of the partial pressure. Now, let us get back to some of those technical details, what we need with is basic understanding.

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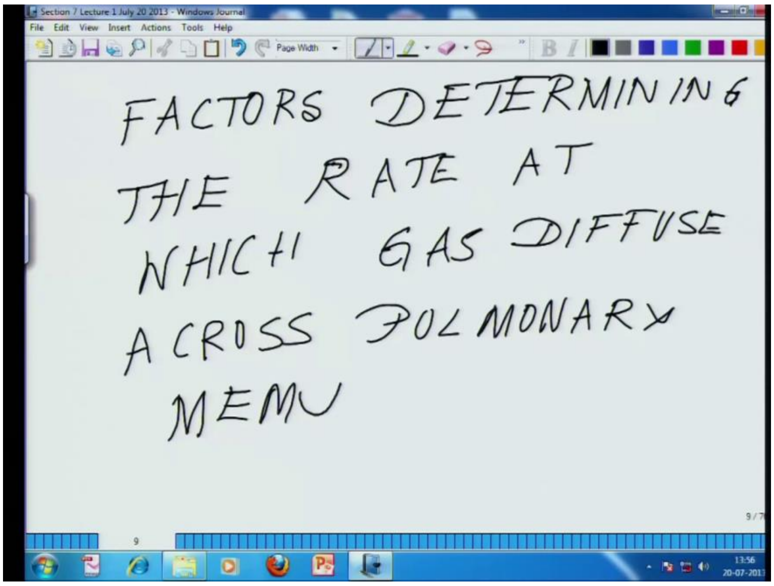

((Refer Time: 20:43)) and, let us talk about the factors determining the rate of, so we discuss now, the partially discussed this, but now I will formalize the whole thing factors determining. The rate by which gas is exchange across pulmonary membrane, the rate at which gases diffuse across pulmonary membrane, across pulmonary membrane. So, there are two factors which governs that, the first factor is the diffusion co efficient of the gas.

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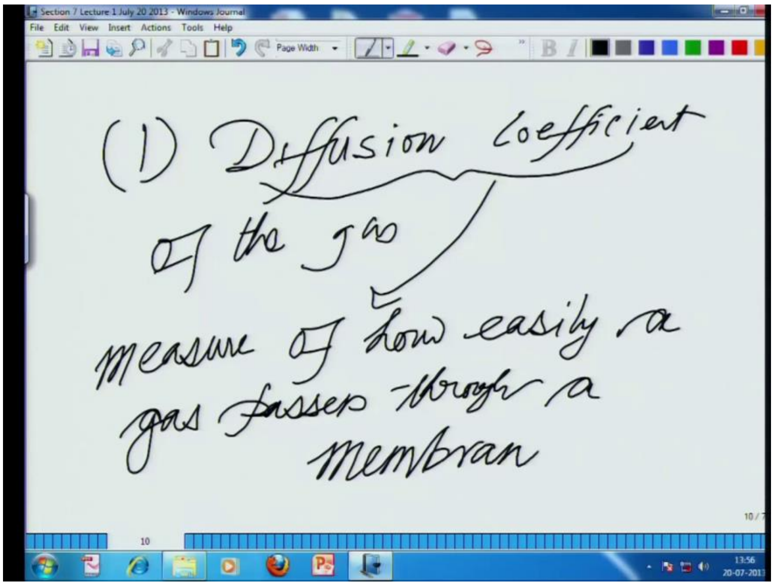

Factor one diffusion coefficient, what is meant by diffusion coefficient of the gas; that means, the measure of how easily gas passes through a membrane is basically the diffusion coefficient could be termed as the measure of how easily a gas passes through a membrane, so that is called diffusion coefficient.

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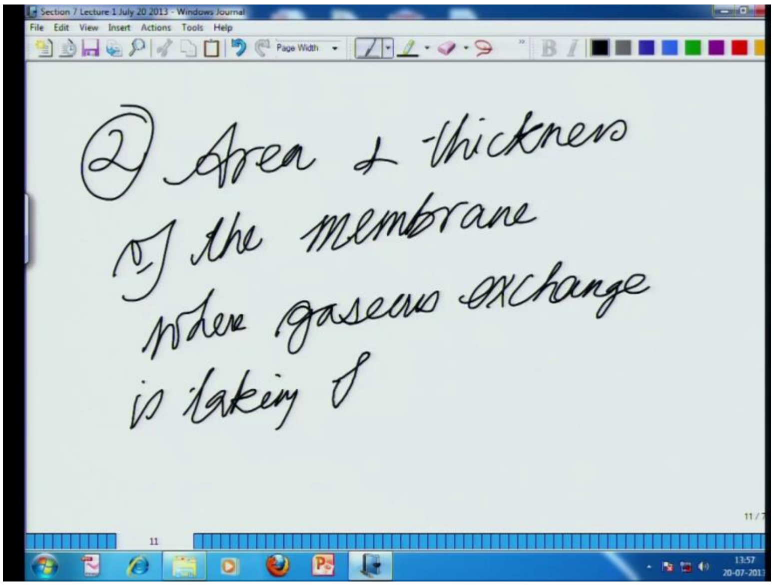

The second factor, which is involved in it, factor two is the area and thickness of the membrane, where the exchange is taking place. Area and thickness of the membrane, where the gaseous exchange is taking place, exchange is taking place.

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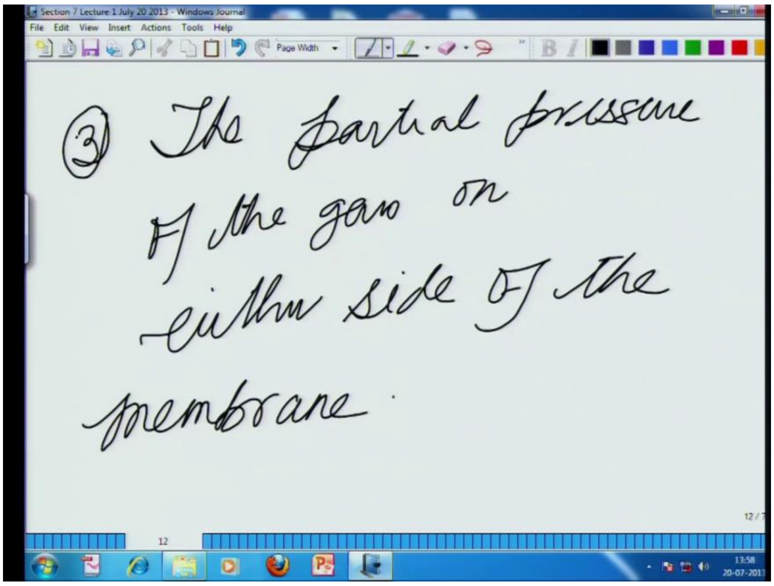

And, the third most important factor, one of the most important factor is, the partial pressure, which I was explaining just a few minutes back, of the gasses on either side of the membrane. These are the three factors, which essentially determines that how the gases are going to diffuse across the membrane.

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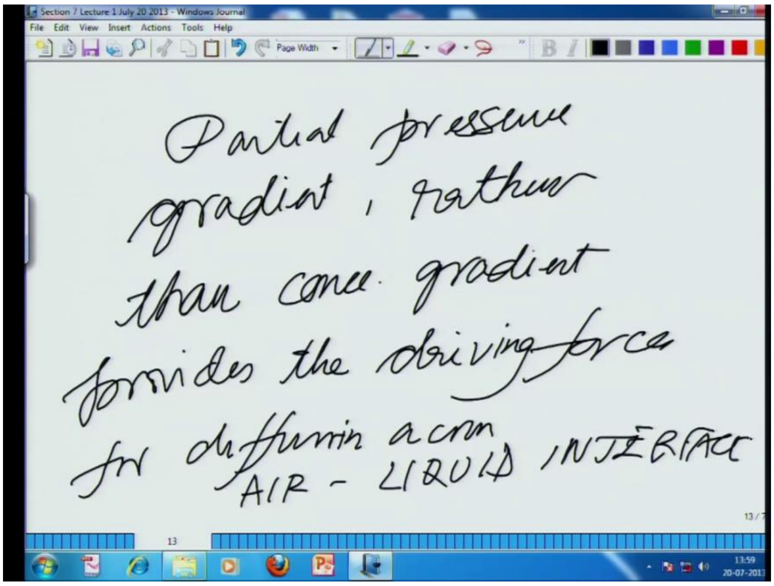

Always remember, that partial pressure, partial pressure gradient rather, partial pressure gradient rather than concentration gradient, this is another way of important rather than concentration gradient provides the driving force, provides the driving force for the diffusion across the air liquid interface. This is important for you people to understand, what is a liquid interface, basically when the gaseous exchange is taking place, it is essentially taking place the lungs alveolus, what I have explained and the blood vessels.

Blood vessel is in the liquid face, all the blood there in a liquid face, where the RBC's are flowing through, where as air face is the alveolus. So, at that zone the unique zone of air liquid interface, it is completely driven by the partial pressure, as compared to the concentration gradient. It is the partial pressure gradient, which dictates Dom at that zone, so coming back to some of the other basic what we need to do.

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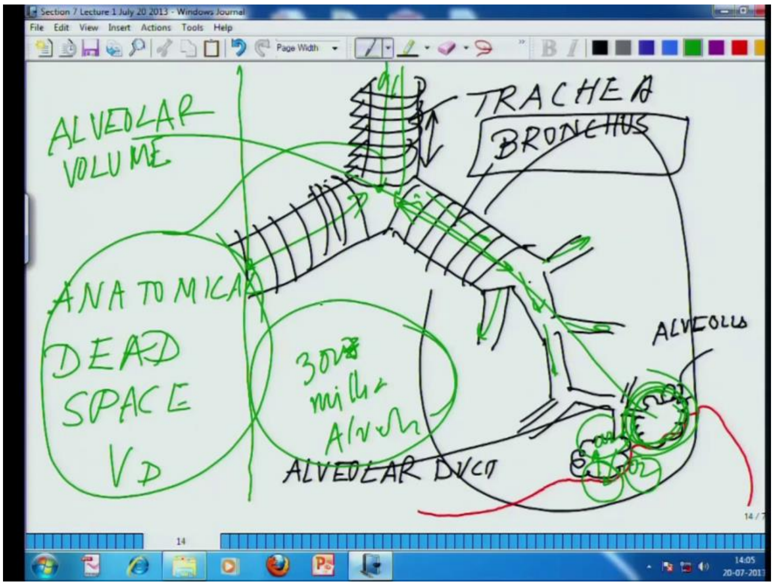

We will talk about, now we will talk about the structure which, I did not complete at that time, so this is basically how the structure of the airways look like. So, this is the trachea, start off with, starting off with, ((Refer Time: 25:39)) trachea structure is something like this. If you look at, any anatomical book it is like you know which are expandable, these are arranged in such a way these can move back and forth and then they split up into two.

And, from here, they enter into each of the lungs, that I drew then the sorry, they further bifurcate, bifurcate keeps on bifurcating and then eventually, what happens as they and they become thinner and thinner as they keep on bifurcating. And eventually, they have this kind of structures which are formed, which are called alveolar duct or alveoli, alveolus, ((Refer Time: 26:29)) sorry for the interruption in between those are slight error glitch.

So, coming back to the structure of the trachea, I did not really go into I told a just I will show you, how it looks like. So, let us look at it how it looks like this is, basically the trachea how it is and you know, it looks like, if you go through any text book, it looks like, it basically those of you who have seen like one slide, over another cylinder, another cylinder, another cylinder, they are slides over each other.

So, that they are flexible, because they have to withstand I am inhaling fast, so the airways, you know have to move back and forth. So, it is a kind of sliding kind of structure, like cartilaginous kind of structure it looks like this, so then this trachea bifurcates into two and then these are called bronchus. So, you must have heard this, bronchitis it was somebody saying bronchitis basically it is blockage on those airways.

Then there is something called, they keep on you know splitting and splitting and splitting, as they keep on splitting into smaller narrower, narrower and narrower diameter. The thickness also keeps on reducing and by the time, they become the alveolar duct, the thickness is almost around one micron it is at that level. But, simultaneously, the surface area goes like I mean crazily huge surface area, where it takes place.

So here, you have the alveolar duct and these are the alveolus, and essentially what is happening, the blood vessels are coming through like this, moving through like this. So, this is the zone, where I was telling you, this is the zone of pulmonary membrane, where all the exchange of gas is taking place your Co2 and oxygen and everything is taking place, this is a critical zone, where this whole process is taking place.

So, coming back to some of the thing, what about the if you look at it, the something which will strike you, if you look at the whole thing this whole process there is no exchange taking place, there is hardly any exchange. There is no exchange of any gases here it is only out here, but yet, this cavit, this passage is always filled with gas. So, that is why this passage, where the gas is stored is called anatomical dead space, or anatomical dead volume.

Basically, that is represented by V D anatomical dead volume, this is not really important and this is the zone, where it is taking place this is called alveolar volume. This is amount of gas, what is being exchanged, and approximately there are even more than, 300 million alveoli even way more than that, I am just giving an approximate number.

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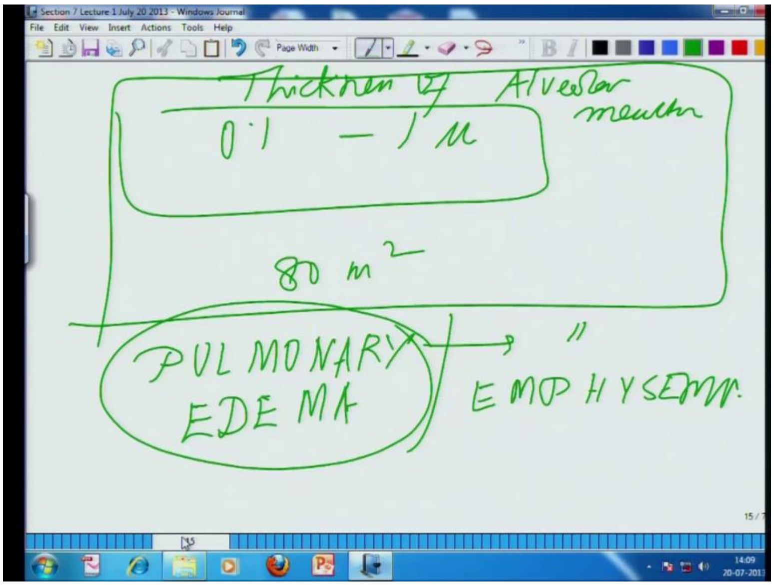

And, if you look at the geometry of the alveoli, that is, it has a thickness of, thickness of alveoli is 0.1 to 1 micron thick depending on which location it is, this is thickness of alveolar membrane. And, it has a huge surface area almost 80 meter square, it is a kind of thing and there are two more things, I wish to highlight here, some of the pathological situations which you may hear, sometime they may call it, when we will be covering the this anyway, just to give you a flare, you hear about pulmonary edema.

Pulmonary edema is basically, anything edema means swelling of something, pulmonary edema is a common disorder which takes place in high altitude, especially in region, where the oxygen tension is very low. Especially, along the northern frontier of India, along the Leh, Ladakh, Sikkim and the north eastern areas of India, along the high altitudes of Himalayas, oxygen is fairly low and this is the place where, because of low oxygen, it leads to hypoxia and the pressure is also low.

So which is, which leads to hypobaric condition, bar means the pressure, hypo means low these are the zones, which have hypobaric hypoxia. Low pressure and low oxygen, and low pressure and low oxygen on top of that low temperature, fairly low below freezing temperature, at times leads to something called pulmonary edema. I will come to the pathology, while I will be talking about high altitude disorders and aviation and everything.

But during pulmonary edema, one of the things which happens is that, what I told you that 0.1 to 1 micron thickness of the alveolar that thickness increases. So, once thickness of, that alveolus thickness increases exchange of gases takes place slowly, so these persons suffers, this kind of situation happens to these people, they cannot breathe properly, as a matter of fact, most of the soldiers who are stationed, in those high altitude, suffers from pulmonary edema.

So, they have to be you know, habituated before or they have to be conditioned, before they can be stationed in those high terrines of the Himalayas for a longer period of time otherwise, you have shortness of breath and other complex situations. There is another side of it there is another disorder called a pulmonary, so if this is pulmonary edema and I request you people, please to go through online and check, these are some very common disorder in high altitude, there is another called pulmonary emphysema.

Pulmonary emphysema is basically, the rate of diffusion in the lungs for x, y, z reasons, may be pathology, may be some other reason, may be some physiological reason the diffusion across the pulmonary membrane goes down very sharply. So, these are the situation when, essentially what is happening think of it from a very global perspective, whenever these gases exchange is going down, in other word your body is not receiving sufficient oxygen.

And, it is unable to throw away the excess carbon dioxide that leads to suffocation and under extreme situation, that may even lead to the death of an individual. These are some of the things, which you people need to understand just by think over it, these are small pieces of information that will lead you people to think over it. And let us move on to, with this over all idea about you know, we are inhaling the air passing through the trachea, moving through the bronchia, from the bronchioles, it moves through the alveolar duct to the alveolus.

Where alveolus is in contact is in close proximity, this is alveolar membrane is this hand is the alveolar membrane and this is the capillary membrane of the blood. There is in close proximity, and this is where, all the exchange of gases is taking place, along these two membranes. And, on this side this capillary side, you have these RBC’s which are present there, which are carrying carbon dioxide rich blood throw away the carbon dioxide, and take in the oxygen.

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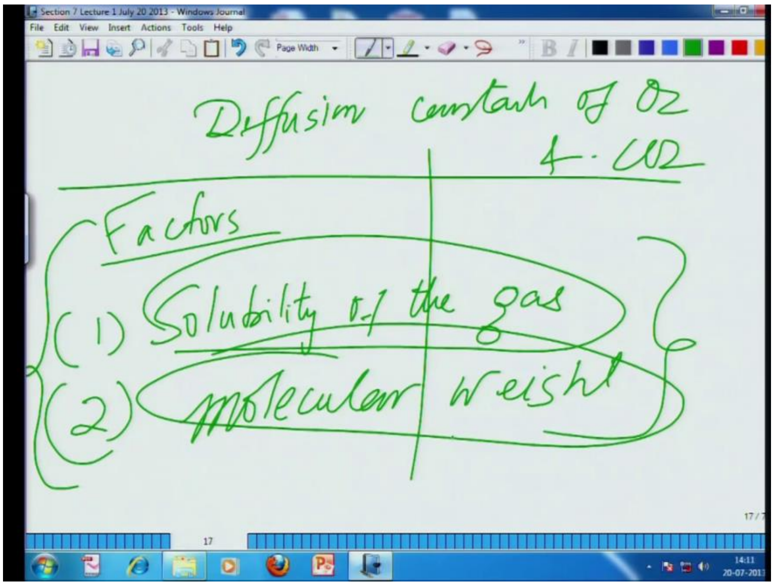

Now, let us come back to the, so coming back to the diffusion aspect of, diffusion constants of oxygen and Co2. So, there are two aspects, which determine there are two factors, which determine the diffusion; one is the solubility of the gas obviously, solubility in the air, in the water. And the second thing, which is determine is the molecular weight, so these are the two factors, which governs the diffusion constant of the different gases, but let me tell you let me give you a very interesting fact on that, if you talk about oxygen and carbon dioxide just think of it.

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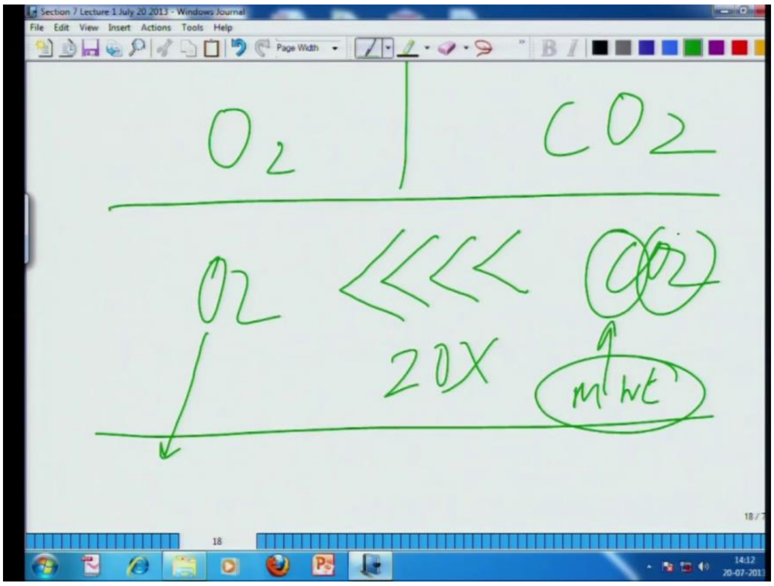

And, I gave you two situations, but if you look at it, if you look at the literature you will find, carbon dioxide diffuses 20 times faster than oxygen. Now, look at carbon dioxide and oxygen I gave you two situations, ((Refer Time: 35:58)) solubility of the gas and molecular weight. So, let us look at molecular weight, so molecular weight wise let me go back, molecular weight wise, the one which is having higher molecular weight will diffuse slowly, because it heavy.

Something which is heavy moves slowly, where as something which is light moves fast, so theoretically carbon dioxide, should move slowly as compared to oxygen, but there is another aspect called solubility of gas, in the water in any kind of moist water medium, so which is more soluble. So coming back here, so this it has been observed, in terms of diffusion, this is almost 20 times more, easily diffusible than oxygen though the molecular wise, this has an additional weight molecular weight of carbon, compared to oxygen ((Refer Time: 36:56)).

But then the advantage of Co2 is that it its solubility is phenomenally high and it is solubility is so high, that it out smarts the higher molecular weight as compared to the oxygen and diffuse much more faster as compared to the oxygen. So, always remember these things there are different factors and they are intricate and you have understand it, and you might ask another question that, in the air we talk about nitrogen. So, nitrogen is not really taking part in any kind of a gaseous exchange in our body, so we are not taking nitrogen into consideration.

So, what I will do is this with this brief background of, overall idea about the whole respiration process is taking place, I will close in here. And in the next class, we will talk about two aspects of it, one aspect will be partial pressure of oxygen carbon dioxide and water vapor, with respect to the total partial pressure as I told you at the beginning of the class, I expect you people to read, this Daltons partial pressure, Daltons law of partial pressure, because that will help you to appreciate it.

And then what we will do, that will be the part one. We will see what are the way, we will be dealing in the next class is, we will have the values we will calculate the values of partial pressure of oxygen, carbon dioxide, water vapor of the air, which we are inhaling fine. Then what we will do, we will measure the partial pressure of oxygen and carbon dioxide, which the blood vessels are carrying and I told you in the beginning wherever for x, y, z for gas oxygen.

Oxygen, if the partial pressure of oxygen is higher in the inhaling air as compared to partial pressure of oxygen in the blood vessel, then the oxygen will diffuse from, higher partial pressure to lower partial pressure. So, for that, we needed all these values, so we will calculate all the values, that is the first thing that we will do, and we will compare in a chart, that this is what we are inhaling and this is what we are throwing out and this is the partial pressure of the oxygen and carbon dioxide, in the blood vessels.

And then what we will do, we will try to understand the mechanism, so first of all understand this dynamics we are done with the anatomy. Now, little bit of the gas, introduction of the different gases, and the partial pressure and the factors, which are deterring it, next we will talk about the gaseous exchange. And, along with it, we will talk about, how exactly carbon dioxide sorry, carbon dioxide and oxygen are being carried by the hemoglobin. What is that chemical association or dissociation, which regulates this oxygen binding to hemoglobin, and under what conditions the hemoglobin rejects the carbon dioxide, which is present there. So, then we will talk about some of the pathological situations, when this situation is being compromised.

Thanks a lot.