Animal Physiology

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Module - 01
Lecture – 29

Welcome back to the NPTEL series of lectures and Animal Physiology. So, we are in the section of Respiration. So, we started with the first lecture of Respiration, were we talked about the structure of the lungs. And how the trickier, which is the cartilaginous structure, split is up into bronchioles and from the bronchioles to alveoli and how the exchange takes place at the alveoli surface; that was the first part.

And we highlighted the fact, that it is the partial pressure difference of oxygen and carbon dioxide, which results in the exchange of gases. Another word, what exactly happening is that the blood which is in reached in carbon dioxide. Releases it is carbon dioxide and fix of the oxygen on which we inhale, this whole process falls another inspiration.

So, in the last class, I told you that in this section, we will be talking about two aspects. One aspect is how we calculate the partial pressure and how we have the complete table of the partial pressure. And, we could see, how this from higher partial pressure, how it goes to lower partial pressure. Especially, in terms of oxygen and carbon dioxide and then, what we will do, will talk about, how the oxygen and carbon dioxide is been carried in the blood.

What are the different mechanisms, blood employs, to carry this at to very, very important gases, which are involved in the respiration as well as metropolis and very much everything in our body and most importantly the buffering. And in the third part; we will be talking about the buffering mechanism with the blood follows in order to ensure, that we do not suffer from any form of acidulous are at clauses as you many people have heard or see.

This is the esteem acid conditions, which ever lead to conditions like cancer and many other things, so do alkaloses. So, we have to always maintain a very stable or kind of a very PH range cannot vary significantly from 7.2 to 7.3. We are slightly on alkaline side, but that is the permissible limit. Other than, certain organs in our body, like a stomach, what we have discussed in digestion, which is extremely low P H. Other than that, most of the body, rest of the body function at a stable PH on 7.4, 7.3, likewise. So, let us start with an as I told in the last class, please go through the Dolts Law partial pressure. So, let us come back to section 7, this is second lecture.

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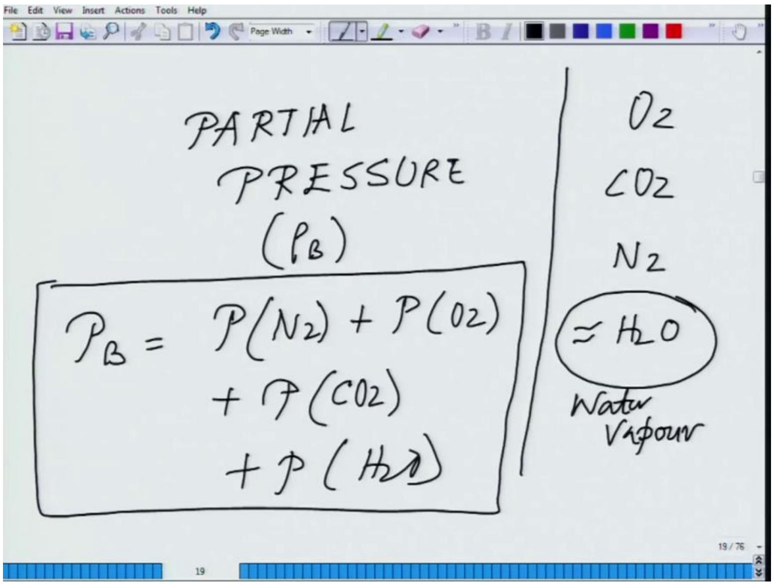

So, if we put the partial pressure, so there are three gases, we are dealing with oxygen, carbon dioxide and nitrogen, which are present in while and of course of significant amount of water vapor N F. That also exhaust it is partial pressure partial pressure partial pressure which we indicates vibes P B. So, P B is equal to partials, P stands for Partial Pressure. Partial pressure of nitrogen plus partial pressure of oxygen plus partial pressure of carbon dioxide and partial and pressure of water vapor.

So, these are the four components, which constitute the complete total partial pressure equation. So, now if you know at least one component and if you know, so always remember this partial pressure is a function of the altitude where you are. So, if you are at the sea level, so that is why, it is in measured. If you are at the sea level, partial pressure is mostly at atmospheric pressure 760 millimeter mercury.

But, if you go up in the mount terms, then the partial pressure the atmospheric pressure decreases. Because on the simple reason, all these gases, what you see their concentration reduces as we go up. As a concentration decreases, so do the partial pressure. So, at different pressure zone, if you are at 760 millimeter mercury, the pressure is different. If you are higher altitude pressure is different and as we go down inside the ocean and the pressure is different, it goes up.

So, these are the basic fundamental, all of you have must studied some pointed or other class 6, class 7 or somewhere other. It is just for you guys, do you know keep that in mind. So, what would be doing here, well we will do the calculation, we doing the calculation based on at the sea level, assuming at sea level 760 millimeter mercury.

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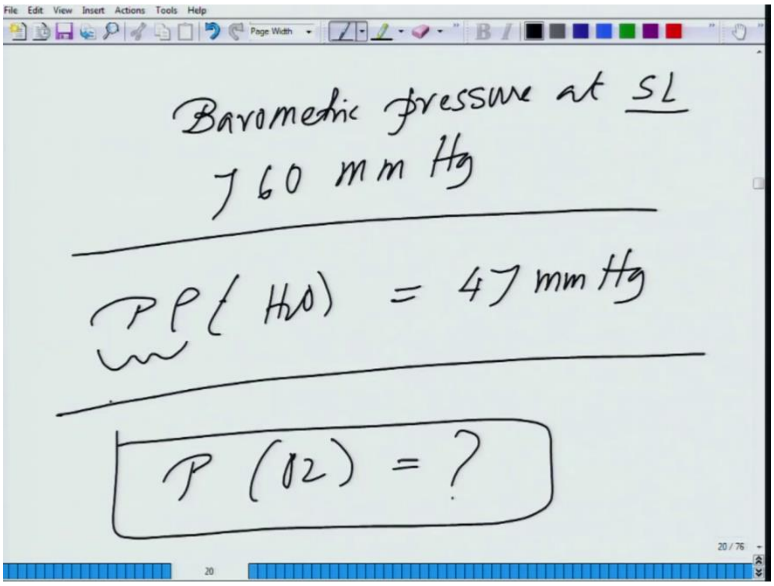

So, it is 760 millimeter mercury. In fact, so when our assumption is very clear, so when the barometric pressure at sea level, I am just putting at SL 760 millimeter mercury. And partial pressure of water, I just put P P, I am talking like that. So, that partial pressure water vapor is 747 millimeter mercury, I give you this value. So, in this value, if I ask you to calculate the, again a confusion there, at this stage, I ask you please calculate the partial pressure of oxygen, what will you do, this is what I am asking me to do.

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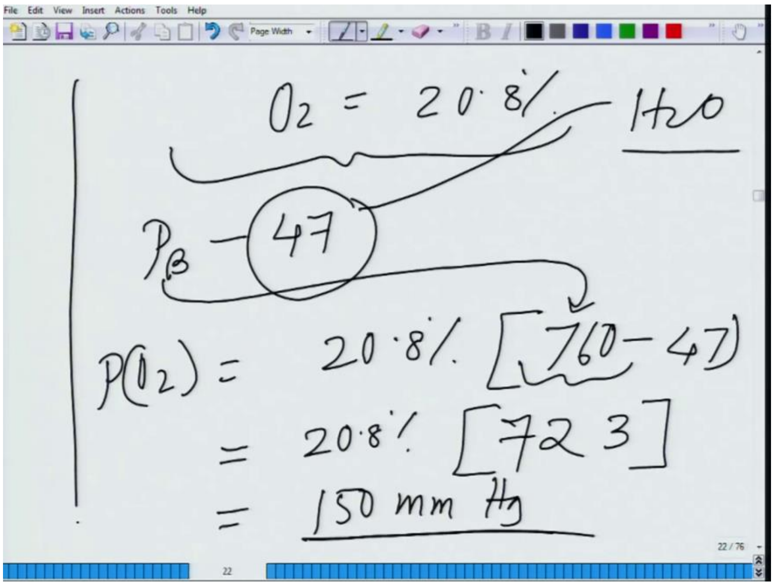

So, we know the oxygen concentration in the air is 20.8 percent. This another value is non T O and the partial pressure is denoted by P B. So, what you do, we know one of the value that is 47, which is contributed by water. So, P O 2, how to calculate P O 2, that will be 20.8 percent of 760 minus 47 and the 760 is coming, add it together at the sea level. So, if you really solve this whole thing 20.8 percent and this becomes 3426 and 723 and if you totally calculate it comes out to be 100 millimeter mercury, this is the contribution of oxygen.

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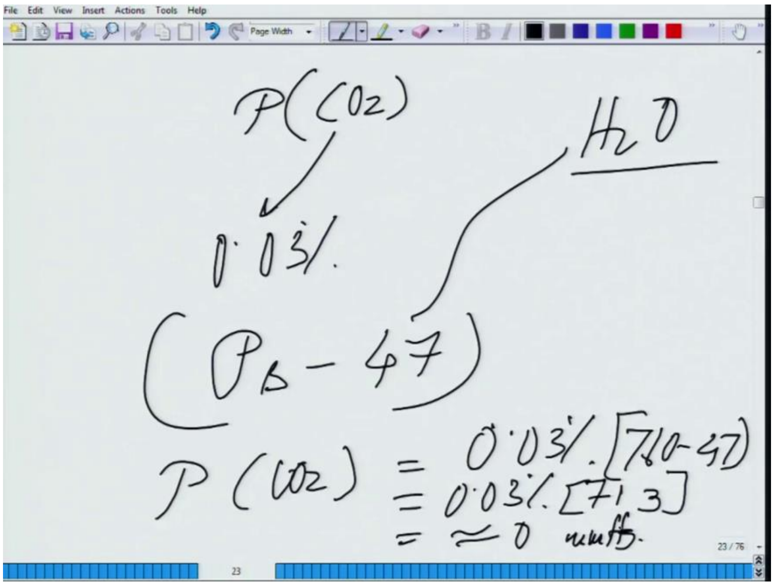

If this is the contribution of oxygen, what is the contribution of carbon dioxide, P C O 2. So for, that you need to know, what is the concentration of C O 2 in the air, which is 0.03, which is very negligible. So, if you how to calculate the P B again, the same thing P B minus 47, which is your contribution from water and then, what P C O 2 become 0.03 percent, 760 minus 47, 0.03 percent. And this value was, how much you calculated was 47. So, 3, 5, 7, 713, so that is fairly negligible approximately almost 0, if you calculated.

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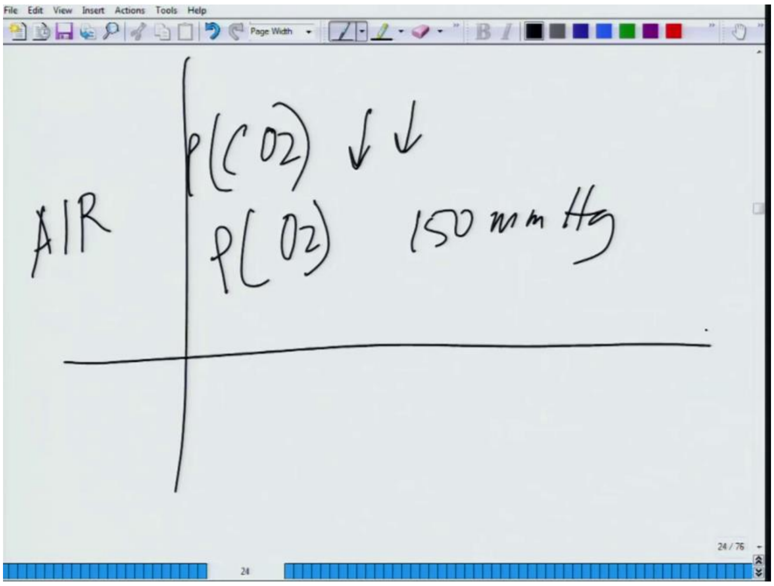

So, basically in the year situation is like this, in the year your C O 2 contribution is fairly low is the regular air. And oxygen, we have talked about partial pressure of oxygen in the air is around 150 millimeter mercury. And at this point, we are only considering with these two gases, because those are the ones, which will help us.

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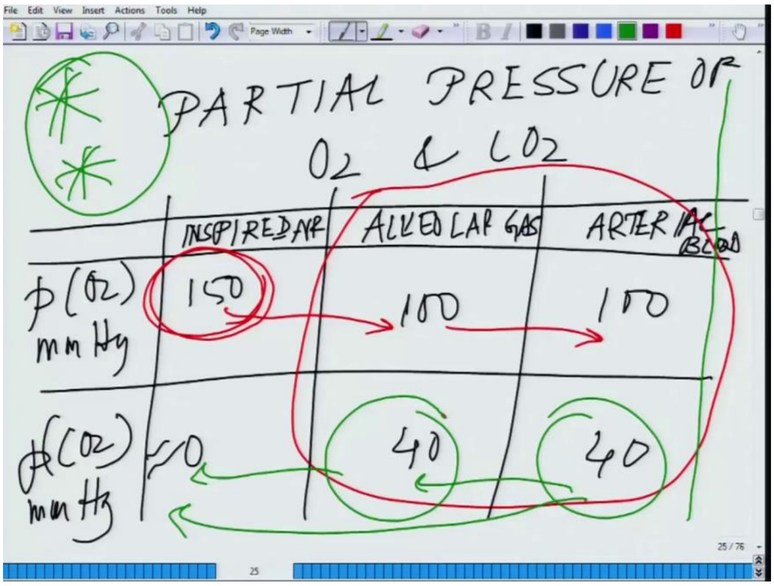

If you really form the table, this is what I was telling you. So, partial pressure of oxygen and C O 2; it will be the calculation two different levels. This is P O 2 in millimeter mercury and this is P C O 2 at millimeter mercury and this is for the inspired air. The air which you are inspired air, we have calculated this as 150 and this is approximately 0. Whereas, alveolar gas, as well as, I am just, both the RTL blood, the blood which is laden in carbon dioxide, which is coming to the lungs for purification, both of them uncured.

This around 100 and where is this is around 40. So, let us consider this as a common, this is at the same. Now, what will happen, essentially what happens is that, here you see partial pressure is higher. So, automatically oxygen gets into the arterial blood. Whereas, here if you lo at the pressure of carbon dioxide is much more higher as compare to outsider.

So, the carbon dioxide moves like this. This is essentially, this is one of the most key things, what you have to kind of realize. That this is how this actual this whole exchange takes place, because of this partial pressure. Use a simple logic, what are you expect the, take home message for the this particular part will be, you have to have a very simple clear cut understanding of partial pressure and atmospheric pressure.

If you know that, the atmospheric pressure, if it is 760 millimeter mercury, I did the calculation. But, if I tell you that you are in a very high altitudes, say macho preacher in

Peru war, somewhere in Ladakh or lay or somewhere Himalayas or in Andies, how to calculate, so what you need to know is, what is the atmospheric parametric. If, you know the parametric pressure and if you have these values reasonably close to it, you can make the calculation.

So, these are the simple ways by which you can make all these. Calculation, which regulates the physiology as will go through your seeds. Now, it will be talking about after this is, how oxygen is carried in the blood. So, if you remember in the last class, I told you in spite of the fact, that the oxygen has a low molecular weight has compared to carbon dioxide.

Carbon dioxide defuses much more higher as compare to oxygen. The reason being carbon dioxide is very reedy soluble. Whereas, in the case of oxygen, it is not readily resoluble, so that pose a problem for oxygen to be carried, so oxygen needs a special treatment to carried all along your body. Because, it is really cannot refuse into the plasma so readily or even it is defuses it is very low concentration, which is not good enough for a metabolism to take place.

So, how the body handles that kind of situation, the way the body handles is this. Body has a specific oxygen carrier, they are found in the red blood cells. So, whenever you go to a Doctor, Doctor ask you, when they do a blood analysis, what is the hemoglobin percentage. Generally, it should be around 12 to 14; sometimes it will falls around 7 or 8 or to force sometimes, even in a reverse case. That means; that there is some problem, because your body is not carrying sufficient oxygen.

So, if the body does not carry sufficient oxygen, what essentially that leads to, is that you metabolism is compromised. Here, a nervous system function is compromising and these are the sum of natural phenomena, which happens in the high lenders and high altitude. Very suddenly you go to high altitude oxygen is low, so automatically the oxygen is low, the hemoglobin is not completely binning to the oxygen. So, these are the kind of situations. Let gets into it and that will help you to realize and there will be some stark difference will come across, how oxygen is been transported and how carbon dioxide is been transported.

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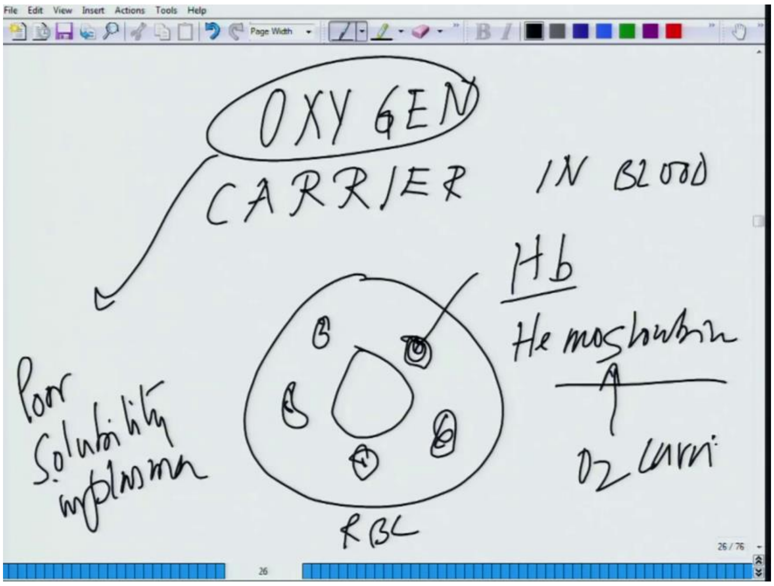

So, let us start with oxygen carrier in blood. So, here you have the red blood cells by concave disk and this, I have already mention, it has a poor solubility in plasma. This is an R B C, within R B C have these hemoglobin molecules sitting there is putting them at H B hemoglobin. This is a protein, I will talk about the protein and which is here oxygen carrier.

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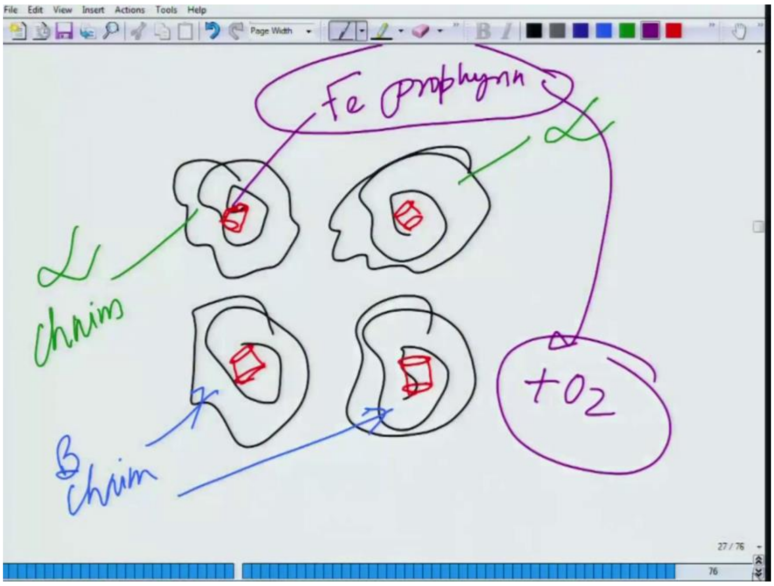

So, if you lo at the hemoglobin molecule, so hemoglobin molecule something like this, it has four sub unit like this and within the sub unit, it has interesting center, this is single molecule of a hemoglobin. So, these two change, this and this one is called alpha change, these are the proteins. And these two changes are called beta change and this red color thing is basically iron prophynn.

This is the one which binds to oxygen, so that is why, you see whenever there is deficiency of hemoglobin. People say, you take iron rich diet or if you have to increase your blood, ecolocily they will say, take iron and rich diet. This is, where the iron place the role and I request you people please go online and check, what is the structure prophynn. Prophynn is basically, I will not give you the full extra structure just look into it.

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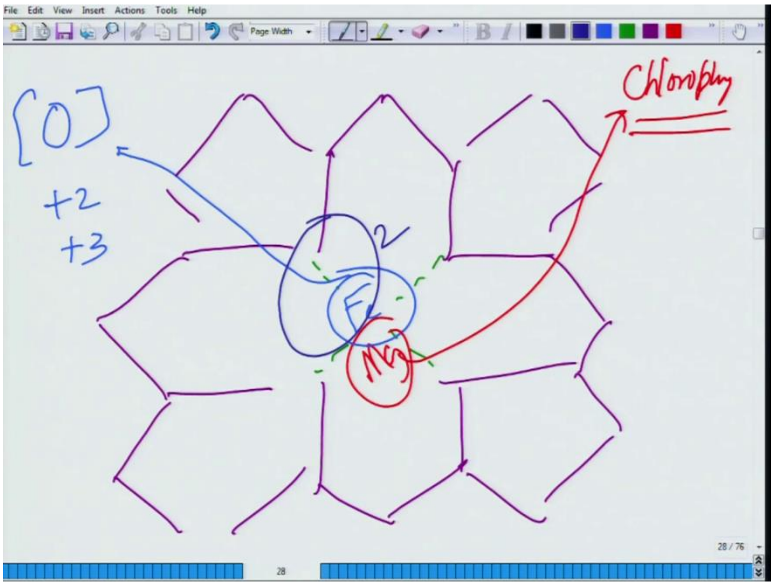

It will be something like, something like a structure, it will come across like this and I want you guys to really go online and check, how all the bandings are taking place, structure like this, will have the iron sitting there. And one more thing, I request you to look at, what is the oxidation in state of iron here, is it plus 2 or plus 3, is it fares or is it ferric.

Please look this, this is the exercise, I expect you people to do and there is another closely molecules to prophynn, were iron is being replaced by magnesium and that is what you called chlorophyll. There are very closed to each other and chlorophyll as you know is the one which helps to trap the sunlight. So, there very close molecules and look into it, I expect you guys to lo into this structure.

So, this is basically the overall skeleton of prophynn and goes through it and looks for the oxidation state of iron. In what oxidation state of iron is stay as prophynn and this is the site where the oxygen is getting bound. So, I will not go into that technical detail of it in depth because, this are not covered in biochemistry, but I expect you guys will enjoy, if you go through it.

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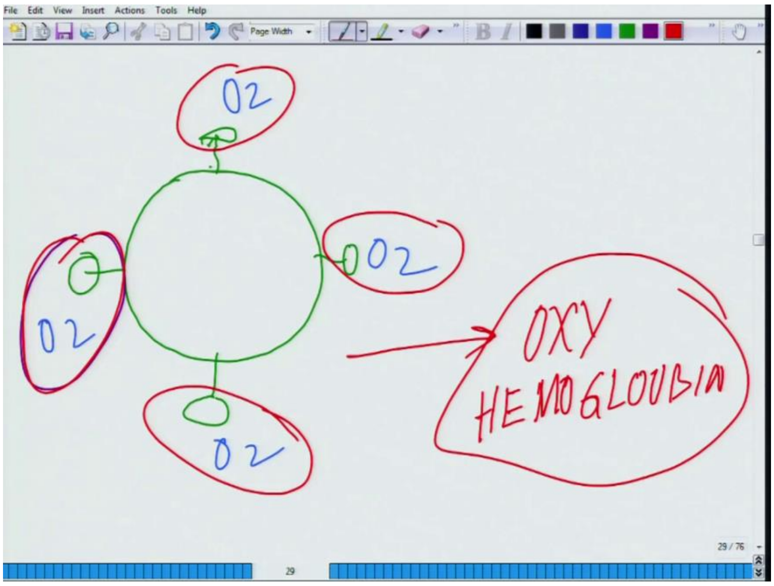

So, there are basically in one molecule. If, I had to say for example, one hemoglobin molecules like this, one hemoglobin molecules could buying to ask you, if you remember in the first diagram, I was doing 2 beta change, 2 alpha change, it is a site to buying to 4 oxygen molecules, so if put blue as oxygen, likewise. So, this is that red zone, the red zone which I was drawing in on other previous lights. So, four oxygen buying, this is called oxy hemoglobin, which is led in oxygen. So, basically oxygen buying very loosely out there, because it cannot buy very harsh, then it would not be able to dissociate.

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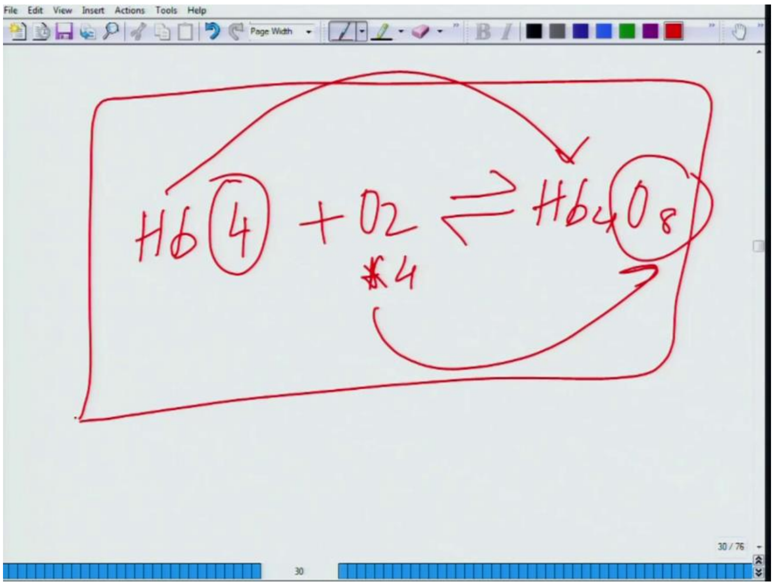

So, basically what happening is that b 4 plus O 2, 4 I put, because there are 4 binding side. Essentially, what is happening is that H b 4 plus O 8, because O 2 multiplied by 4 that makes is it O 8 and before this O 8 is coming. So, this is basically, how the oxygen is binding and based on the saturation level oxygen, you can term it as.

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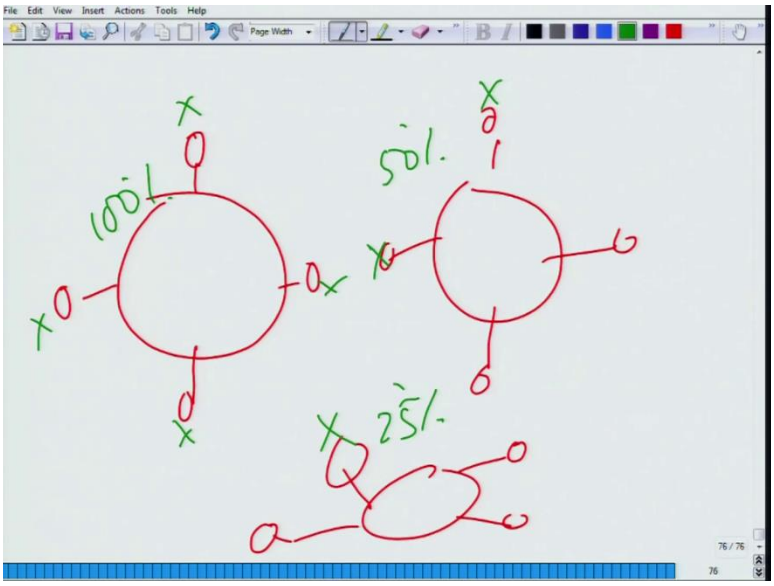

Likewise, if there is only, if all the four sides are occupied by oxygen, this is 100 percent saturated. If 1, 2 are this 50 percentage, if only 1 is and it is 25 percent. If none, this is unsaturated.

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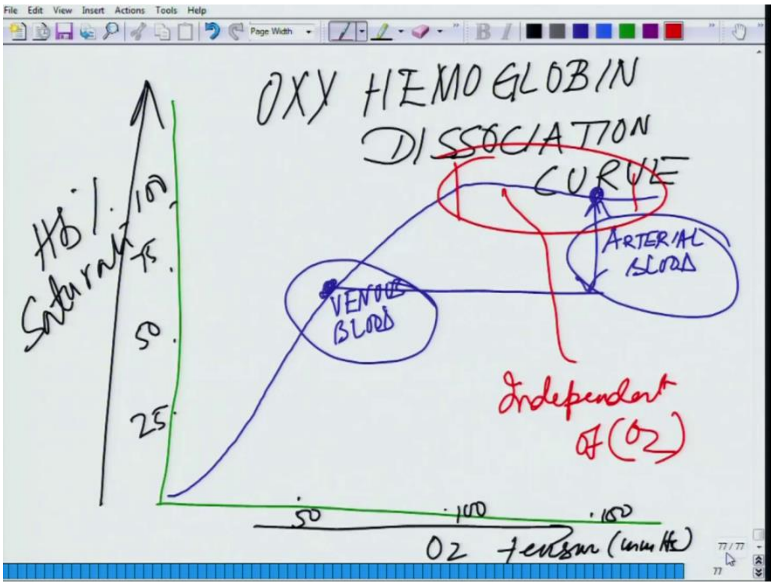

And based on these, you can draw the saturation, which is also called oxy hemoglobin dissociation curve. This is basically, what you essentially say this, all y axis, you have hemoglobin salutation, telling you saturation, it could be 25 percent, 50 percent, 75 percent, 100 percent and where as on the x axis, you have oxygen tension in millimeter mercury.

So, this is the 50, 100 and 150 likewise and if you draw the graph, it shows an almost S shape curve here and if you look at somewhere here. It will be the venues blood, which has lower saturation of oxygen, as you know that most of the oxygen is been used as by the tissue and if you look somewhere out here, this is arterial blood, which is filled with oxygen. Expect the retrial, which is taking the carbon dioxide rich blood and you can do to the lungs.

And, you can see that difference in the hemoglobin saturation of oxygen and at this part of the curve; this is almost independent of oxygen concentration, because as long as it has binding sides. The entire hemoglobin molecule has a limited number of binding sites; it has only four binding sides, so assume a situation, when all the hemoglobin plus all the red blood cells are completely saturated with oxygen.

So, you do not have any other part where oxygen combine and we have already say the oxygen dissolving power solubility very, very low. So, automatically there is no room for oxygen, where we need to find, so under that situation this curve reaches a peak, what you see a plato, the plato is reached. Because, there is even if you add oxygen at that point of time, there is no point, because, there is no more oxygen binding site left in the hemoglobin, because they are all filled.

So, when the plato reaches, it is free from any oxygen concentration. So, remember that, this is very important to understand, coming back to where we were. So, this is the zonal, which I am trying to highlight, this is completely free from oxygen and another thing, which I wanted to highlight here, is that at this zone look at it.

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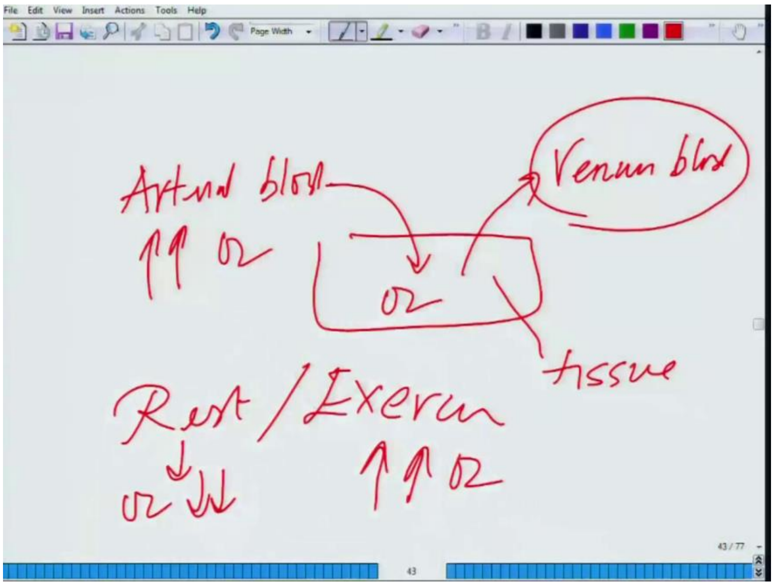

So, essentially what is happening here, when the arterial blood is coming, arterial blood and the venus blood, this blood is coming with very high oxygen and then, when it goes to the tissue and this is the tissue. This tissue in this box is a tissue, it gives away the oxygen and picks up the carbon dioxide, it is here you can figure out, if you see the saturation zone; that is what happens oxygen tension is lesser out here.

And if you see the previous graph, it was exactly like that and this oxygen tension changes further during two different guidelines, whether you are at rest or whether you are at exercise. At rest, your oxygen consumption is low, low oxygen consumption, where as during exercise oxygen consumption is much higher, so automatically, the saturation goes much faster.

So, remember that the lower part of the graph, where basically the venus blood is having a lower oxygen tension. So, see that graph and that graph that is reached very fast, when you are doing a lot of exercise, so this is something, which I expected you people to you know understand.

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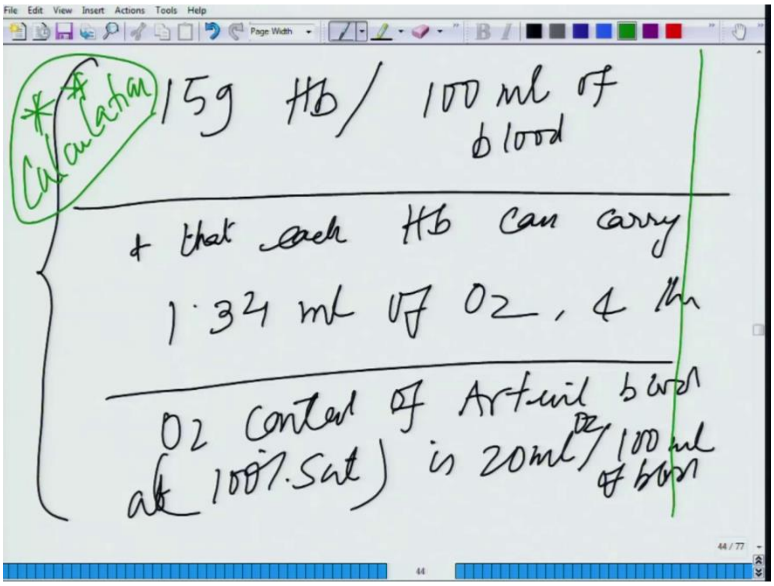

From here, I will move on to the next slide, where basically some of the fact, what I except you guys to understand is that, there is 15 gram hemoglobin is present in 100 ml of blood, this will help you in all kind off calculation. So, this is basically, what we talk about, how much hemoglobin is present in that. Each, hemoglobin can carry 1.34 ml of oxygen, this is very important. And the oxygen content of arterial blood at 100 percent saturation is 20 ml oxygen per 100 ml of blood.

These are some bit is and pieces of information, which will help you to do any kind of calculation, so that is, why I wish to high light this is very important for all the calculation purpose. If you know this values, it will fairly easy to do any kind of calculations. After the oxygen’s, we talked about the hemoglobin and talked about per fired structure hemoglobin, let us talk about carbon dioxide is been carried in the blood.

So, in case of carbon dioxide, there are three different mechanisms, as such there is no specific carrier, that of course, hemoglobin does bind to carbon dioxide and it called carboxyl hemoglobin. Just like the oxygen hemoglobin, when oxygen binds to hemoglobin, there is also whenever oxygen is been thrown out and carbon dioxide binds to it, that is called carboxyl hemoglobin. So, apart from carboxyl hemoglobin, there are two other roots by which carbon dioxide is been caring. So, what will do now, we will enumerate all the different roots, by which carbon dioxide is been carried out, is been carried all over the body.

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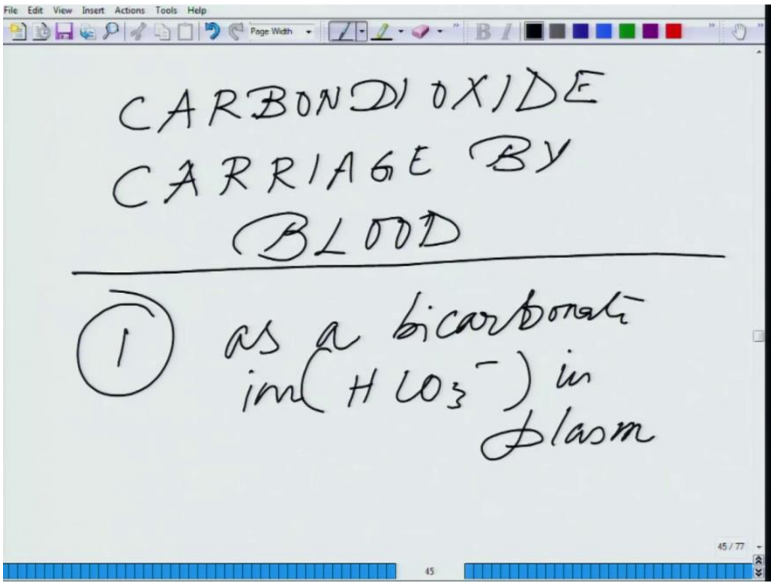

So, let us get back to carbon dioxide carriage by blood. And this is very readily soluble in the blood, I have told you. So, first is, as I and I will discuss all of them separately as a bicarbonate iron, which is a C O 3 minus in plasma, this is root 1.

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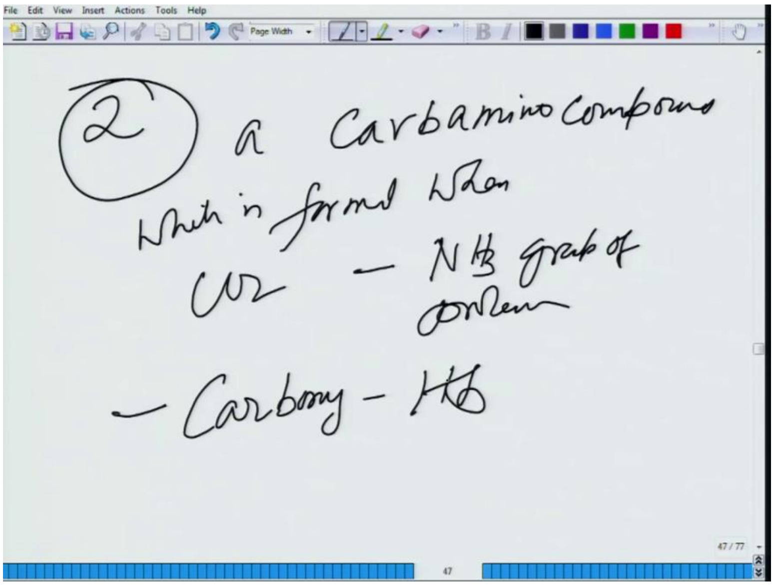

Root 2, a carbamino compound, which is from, when C O 2 and N H 3 group of protein resist. Essentially, we are talking about carboxy hemoglobin.

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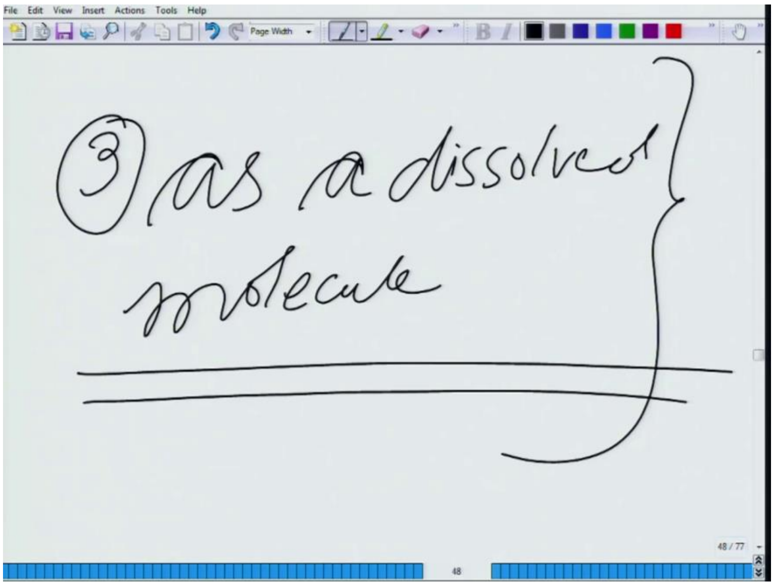

There is a third way of caring, which is as a dissolved molecule, this is easiest. Because, it has the highest solubility, I have already mentioned that, these are the three different ways, why by which carbon dioxide can be transported. So, how it does in the bicarbonate, because that has significance in P H that is why, I will come back to that.

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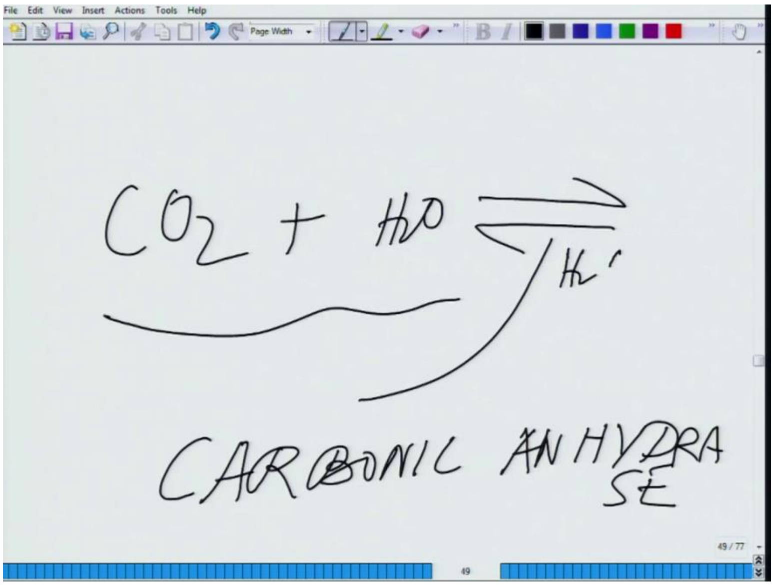

C O 2 plus H 2 O, when this two mix there in enzyme, which is present in the body which is called Carbonic An Hydrase, what Carbonic An Hydrase does is that transform it to h 2 C O 3 to go to the next page.

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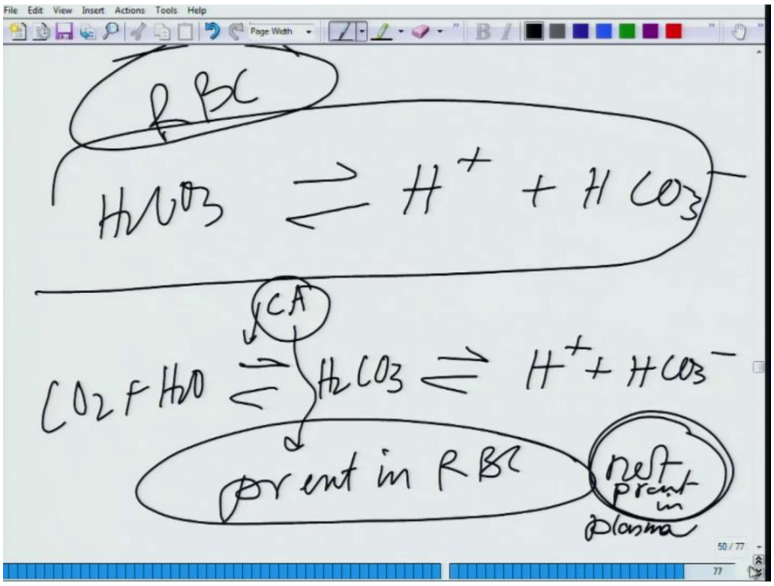

To complete the reaction H 2 C O 3, basically has ability to disassociate the H plus H C O 3 minus, so if I put the whole reaction in perspective, than this is like this C O 2 plus H 2 O reversible reaction. This is what C A carbonic a hydra comes to a play, H 2 C O 3 and from here it breaks down to H plus H C O 3 minus. And this Carbonic An Hydrase is present in only in R B C, is not present in plasma, mark my word not present in plasma, so this reaction has to take place inside the R B C.

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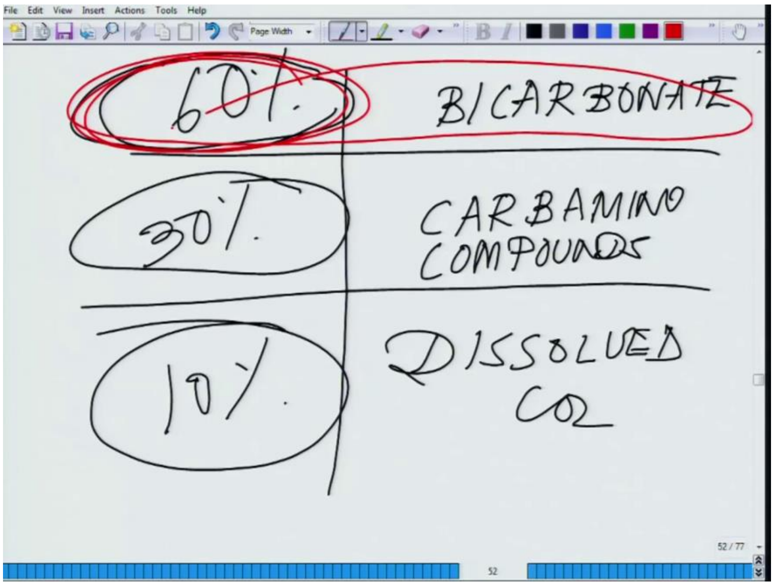

And if you have to do a complete outline that, which of this component is contributing how much for carbon dioxide travel and you will see. So, let us enumerate them, one is the bicarbonate we talked about bicarbonate, carbamino compounds, and then we have dissolved C O 2. So, this is 10 percent dissolve one, carbamino compounds of that is carboxyl hemoglobin. Likewise is 30 percent and the major chunk is in the form of bicarbonate and this is very important that bicarbonate is the one, which carries the maximum amount of it.

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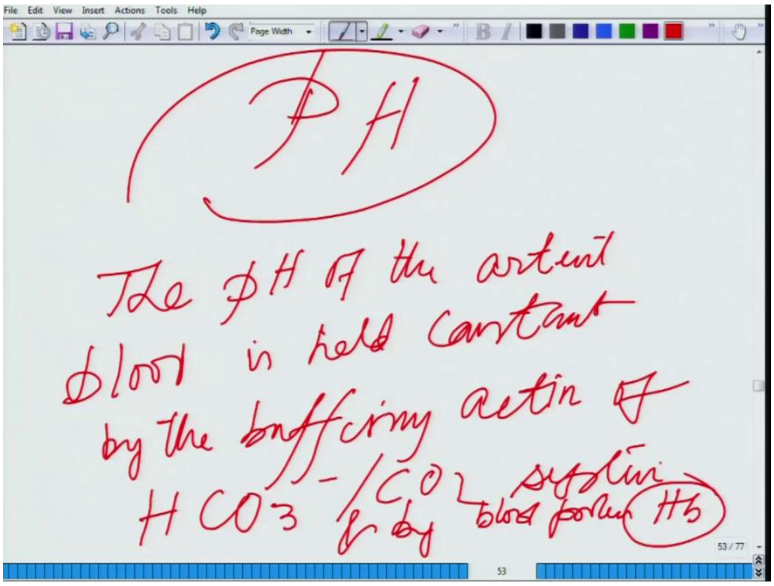

And from here, what I will come to the concept of P H, how P H is been regulated, so this is a very important fact, that you have to realize that P H. So, in the beginning lecture, I told you that P H are exceptionally asexual in terms of maintaining the proper homieo stresses of the body. So, the P H field if you go back to that reaction, if you remember the reaction is just trying to draw, carbon dioxide plus water making it H C O 3 and then H C O 3 is H 2 C O 3, H 2 C O 3 is disassociating in to H plus H C O 3 minus.

This reaction is one of the most fundamental reaction and depending on forward reaction, backward reaction, rate of forward reaction, rate of backward reaction; because we have two controls zones. This is the one, which helps to maintain the P H and that is what, we are going to deal now. How, this particular reaction helps to maintain the P H of the body.

The P H of the arterial blood is held constant. So, this the one, which is helping in the whole buffering, by the buffering action of h C O 3 minus and C O 2. This is very important C O 2, this is as system, which helps in all our buffering and by blood protein, which is mostly blood protein which is involved is the hemoglobin.

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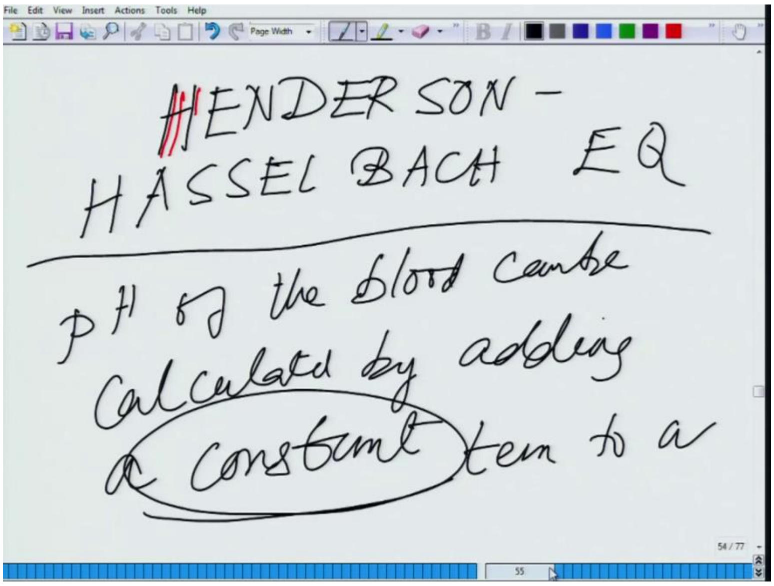

This is something, which we have to realize and this could be stated by the Henderson Hassle Bach creation and please go through this those of you have forgotten. Basically, using Henderson Hassle Bach creation, we can formulate that P H of the blood can be calculated by adding a constant adding.

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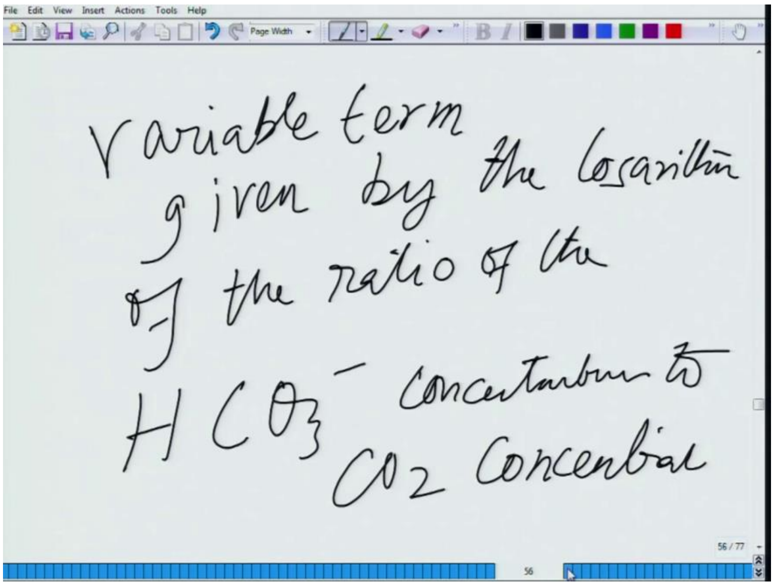

So, there it is adding a constant term to a variable term given by the logarithm of the ratio of the H C O 3 minus concentration to C O 2 concentration.

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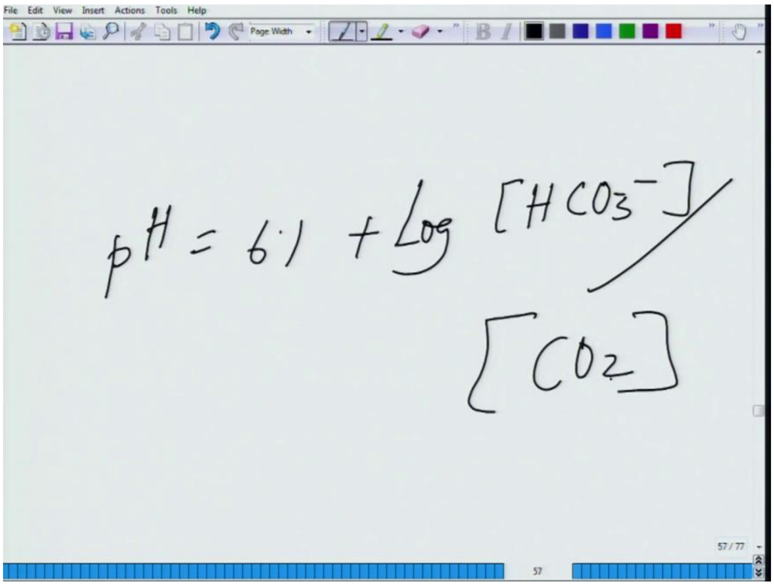

And, if I put the mathematical equation, here that will be the P H is equal to 6.1 plus log of H C O 3 minus mono concentration divided by concentration of C O 2, this is very, very important.

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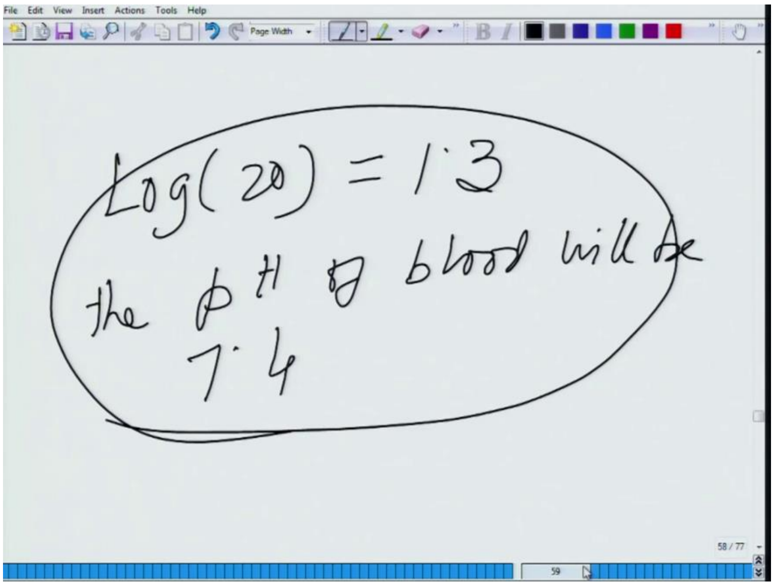

And, if you see that, if you say the value of log 20, which is equal to 1.3, the P H of blood at that situation will be 7.4.

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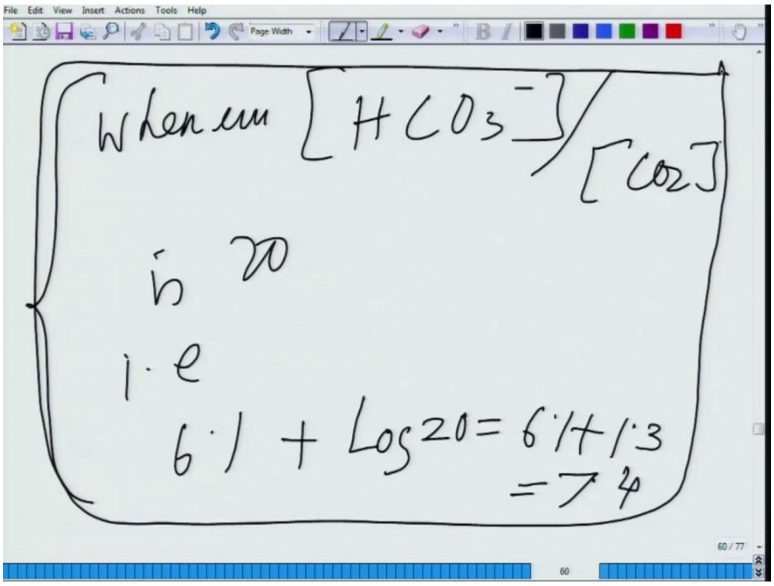

So, in order to have a 7.4, what will be the situation is, so whenever H C O 3 minus up on C O 2 is 20, that is 6.1 plus log 20, which is equal to 6.1 plus 1.3 makes it 7.4. So, what are the implicates, so if you look at it, this values if you know that the Henderson Hassle Bach equation that P H is equal to 6.1 plus log of a C O 3 and upon C O 2. Then, you can make this whole calculation without any problem and this is exceptionally essential and what is the implication of Henderson Bach.

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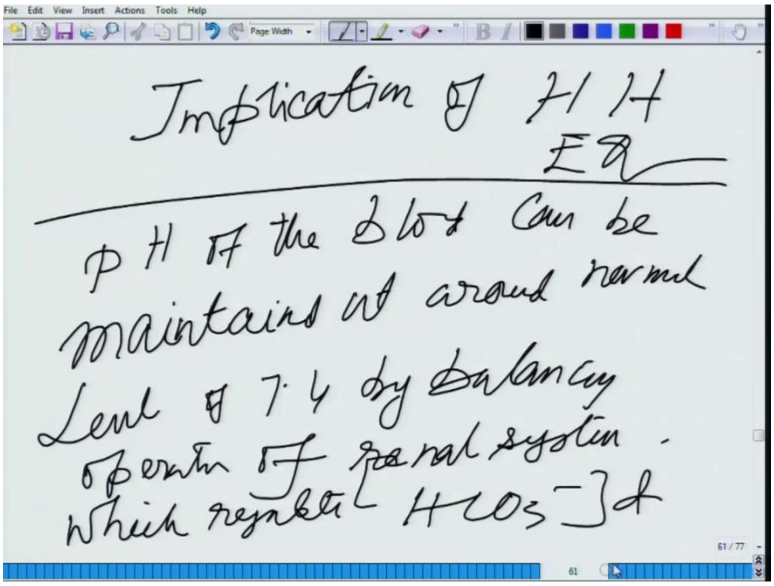

So, let us talk about the implications of it am just putting H H, Henderson Hassle Bach equation. Now, P H of the blood can be maintained at around normal level of 7.4 by balancing operation of renal system, which is your kidney system, which actually regulates, which as you come to the kidney. You will realize this actually regulate H C O 3 minus concentration.

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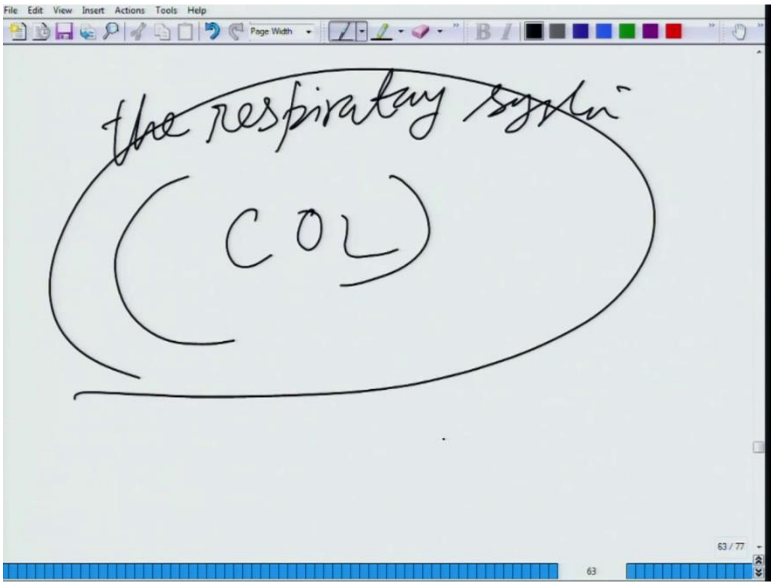

And the respiratory system, which regulates your carbon dioxide concentration, so this is exceptionally important for you people to realize that, these are the two situations, which regulates the P H.

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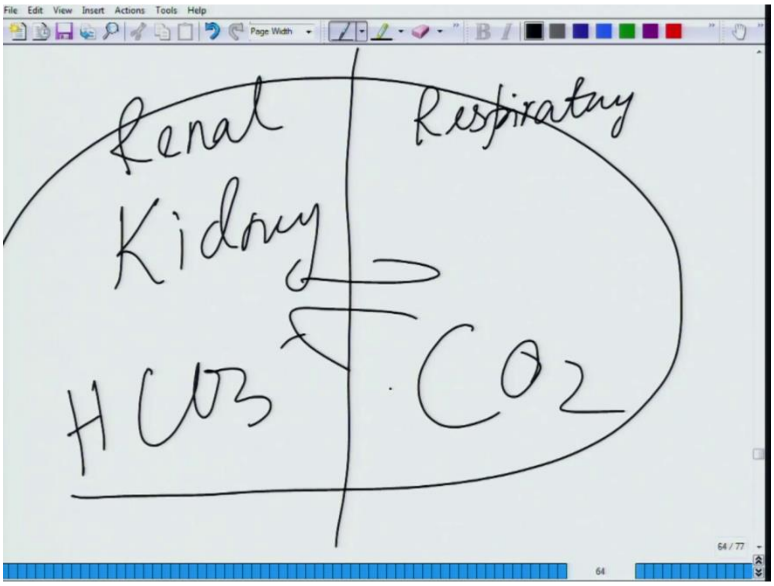

So, you have a inter play of kidney or the renal system and respiratory system. So, this is regulating C O 2, this is regulating H C O 3 minus as long as this are properly balance, your P H in the body will be will be balanced.

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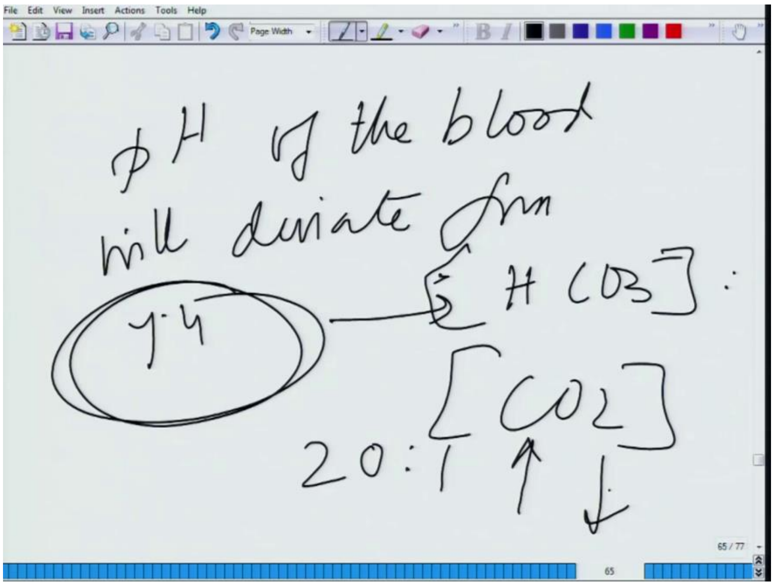

Another thing, for you is important to remember is that, P H of the blood will as this is just a direct implication of it, will deviate from 7.4, which is the normal value. Whenever, here H C O 3 minus is to C O 2 ratio of 20 is to 1 shift to the upward or downward.

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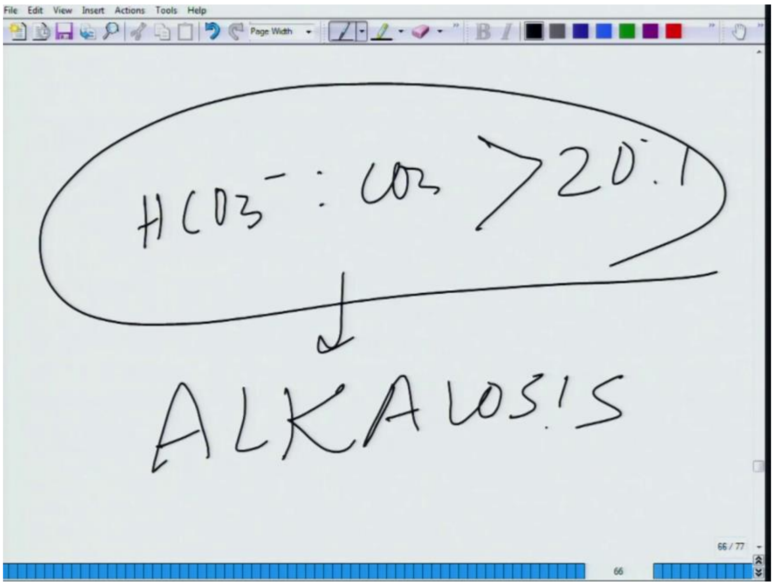

If for example, if your H C O 3 minus C O 2 ratio is more than 20 is to 1. Then, we are hitting on to situation called Alkalosis, it means the body is alkaline.

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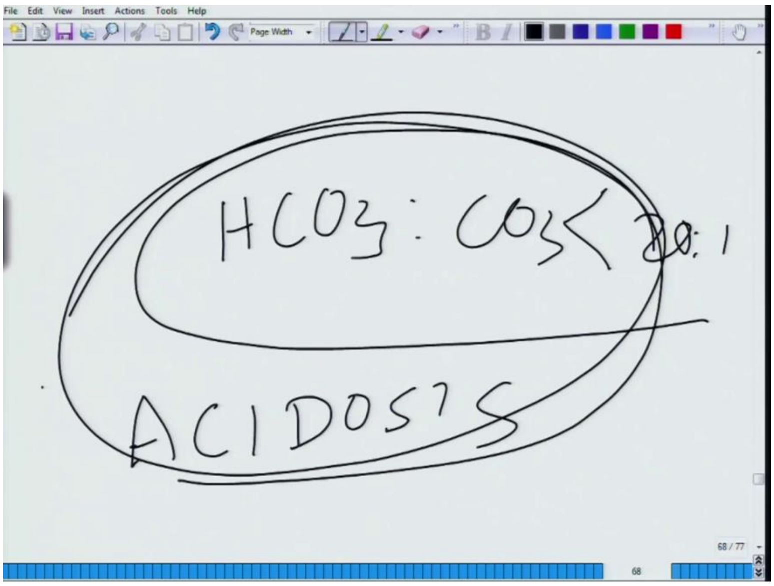

Whereas, if h C O 3 and C O 2 ratio is less than 20 is to 1 and we are hitting into acidosis. So, this is what you have to remember very clearly and there are couples of more terms, which are very essential.

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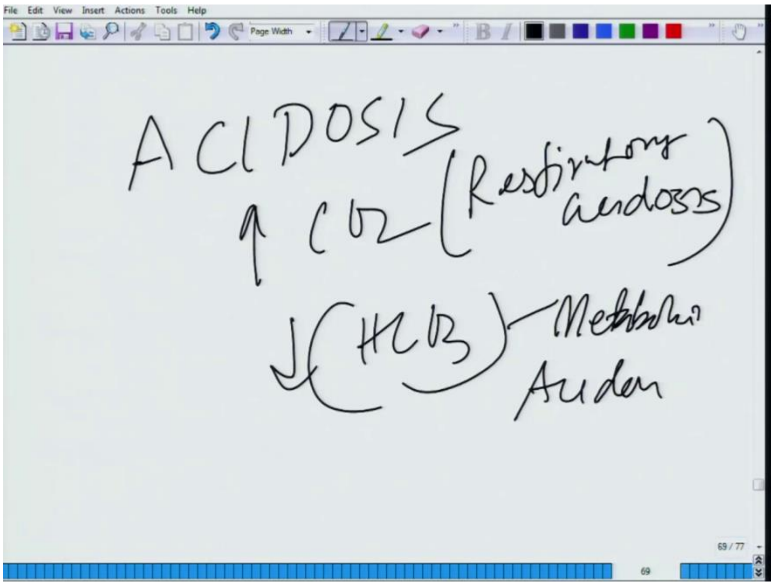

Acidosis could be because of this, this is basically high level of C O 2 and lower level of H C O 3, which is basically called metabolic acidosis and this called respiratory acidosis, because for a simple reason that C O 2, percentage is governed by the carbon dioxide. So, whenever C O 2 percentage or goes down, goes up, it is at the respiratory acidosis or alkalosis. Whereas, in case of H C O 3 concentration which is regulated by the kidney, it is basically the metabolic acidosis or metabolic alkalosis.

So, these are that aspect, which we covered today, we talked about the partial pressure of carbon dioxide and oxygen in the air, which we inhale and the level of carbon dioxide in the blood. Then, we talked about the carriers of oxygen carriers of carbon dioxide and then, we talked about, how this C O 2, H C O 3 buffer system helps to maintain the P H of the body. So, this are the overall things and kindly go through the notes, which I have given you here and that will help you to understand. And always be very clear about your basics.

Thanks a lot.