**Animal Physiology**
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**Module - 1**
**Lecture – 7**

Welcome back to the lectures in Animal Physiology in a NPTEL. So, we have finished first three sections, we started with the introduction to physiology, where we covered two lectures, then we moved on to membrane physiology, where we talked about the structure and dynamics of the membranes, we covered three lectures and then we moved on to the heart, the pumping station of blood in our body. So, in that we finished, three lectures where we talked about the structure of the heart and the dynamics, including the conduction and contractile system.

Now, we will move on to the fourth section of this course, that is the blood vessels and circulation. So, now we have fairly good idea about, how the heart is pumping the fluid, so now, what we will study is the vessels of the tubes, which forms a huge network all throughout our body. In order to supply the oxygenated blood carry bag the deoxygenated or carbon dioxide reach blood back to the heart and which is being transmitted to the lungs for further purification.

And, what are the features of these different vessels, which are carrying the oxygenated blood and the features of the vessels, which are carrying the deoxygenated blood. What are their specific characteristics and what are the conditions, which lead to some kind of pathological situation that is what we are going to discuss now.

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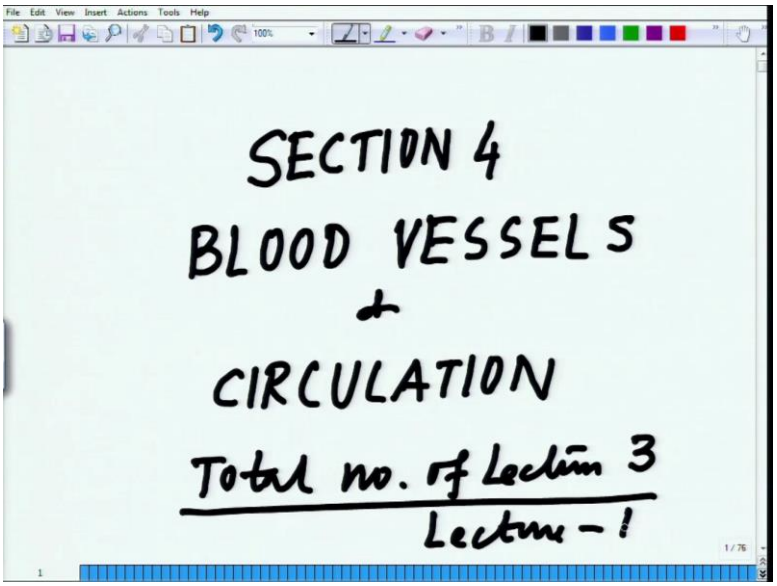


We are in section 4, we are in section of blood vessels and circulation and on this, we are in there are a total number of lectures will be 3 in the section and we are into the lecture one of the section.

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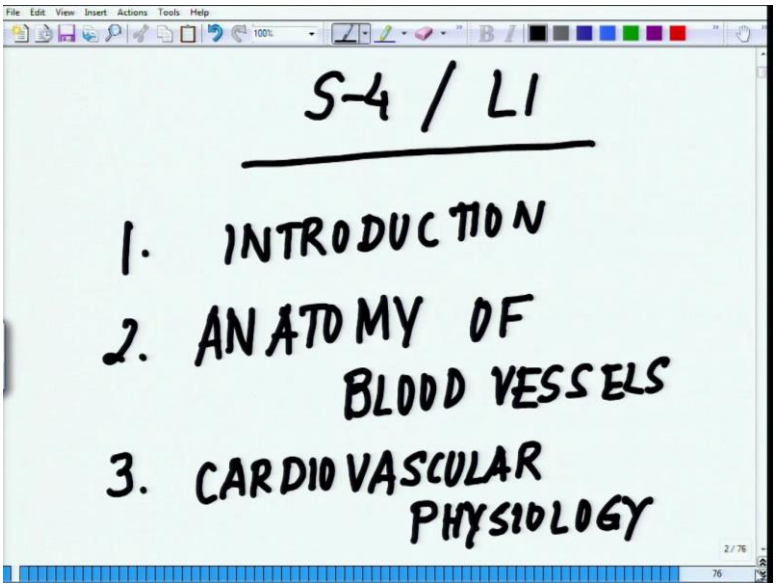


So, in this section 4 and so this lecture 1, in this section, what we are going to cover is the basic introduction of the circulatory system. Introduction, especially in this class; we will be talking about the introduction and the anatomy of blood vessels. These are the two interesting aspects, we are going to deal in this lecture and third we will be moving

on to cardio vascular physiology. Well, we will be talking about the different pressure Regman, which are needed.

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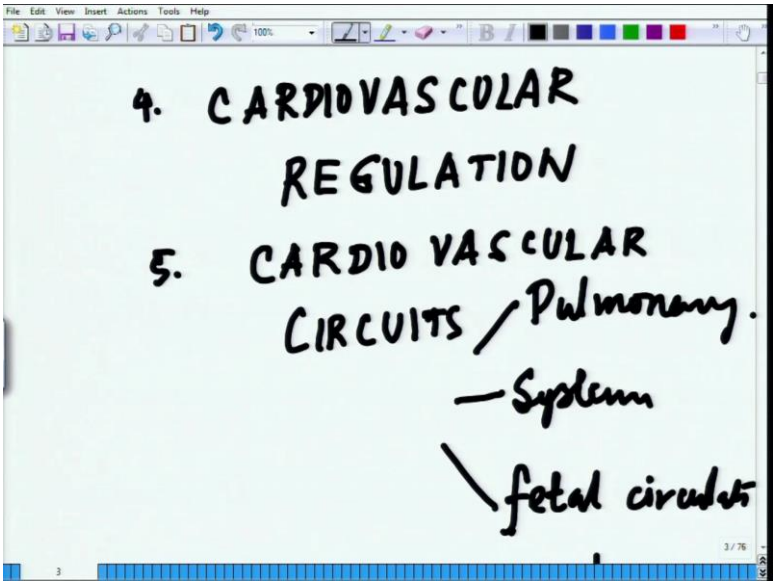


And in the 4th, we will be talking about Cardio vascular regulation and then in very brief, we will be talking about the different Cardio Vascular Circuits. And in those circuits, we will be talking about three different circuits; one will be the fetal circulation, which is slightly different from the angular circulation. And, we will talk about the systemic and pulmonary. Lot of it, we have already done, so it is just kind, so bit of repetition of it.

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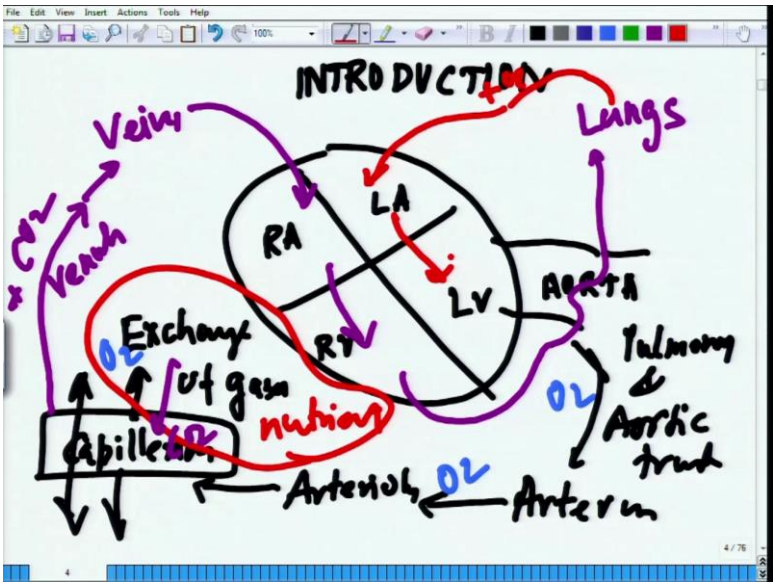


Coming back to the introduction, so as we are already talked about the heart and which consists of four chambers, we know that right atrium, left atrium, right ventricle and left ventricle. So, what is happening from the left ventricle blood is coming out through the aorta and reaches the aortic trunk and pulmonary and aortic trunk, from here this blood moves to the arteries. Arteries are the one, which are carrying the oxygenated blood from the arteries; it moves to arterioles, which we will talk about dimensions of these arterioles.

From arterioles, it moves to the capillaries, capillaries are having the smallest diameter, we will come to that and capillaries is the zone, where these are maximum exchange of nutrient gases takes place, exchange of gases, then nutrients all takes place at the capillary bed. This is the major exchange zone from there, the deoxygenated blood as of now, this is all oxygenated blood which is coming and this is where most of the oxygen is being given off and all the carbon dioxide is being taken in by these vessels and this carbon dioxide reach blood.

Now, through the venuels reach to the veins and the veins come back to the right atrium and from there it moves to the right ventricle, from here it by passes everything and moves to the lungs, where it gets purified. And, then again the oxygenated blood plus oxygen blood come to left atrium move to the left ventricle, so this is how it goes.

So, if you look at the major zone, where the maximum exchange of gases and fluid is taking place that is taking place in the capillary layer and those are very specialized structure as an amoato fat. In this whole vessel, that those are the perforated or fenestrated and come to those in depth in detail, those are very, very special zones and in this capillary beds are all around our cells.

And, all the cells are kind of breathed continuously by the capillaries all around them, which allow the maximum exchange of the excretory materials to be reabsorbed, the gases which has to be reabsorbed like carbon dioxide. And, those gases which have to be giving to these cells take care of all the metabolic activities.

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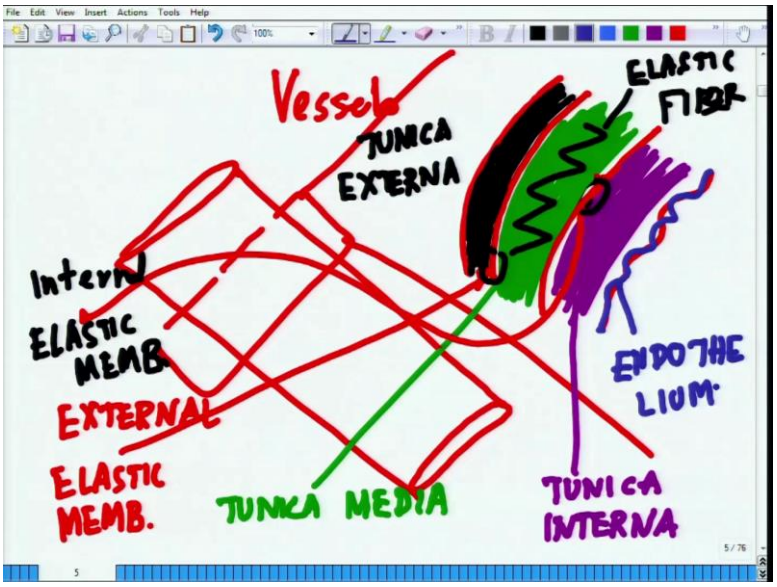


From here, we move on to the bigger classification of the vessels, so before we move on to the vessel classification, let us see how the vessels look like, very basic idea about the vessel. So, most of the vessels are like cylindrical vessels, which are continues, so if you take a cross section of this vessel, something like a cross section view. So, the cross section view of a vessel is like this, there are different layers on it, there is an outer layer, there is a medium layer, medial layer and there is an internal layer likewise.

So, this is the outermost layer, which is called this is the outermost layer and all the vessels have this, this is the common feature. They have Tunica Externa, this is the outermost layer, Tunica Externa, then there is a middle layer that is called Tunica Media this is this layer in the green color, this is called Tunica Media. And, then there is a third

layer which is I am putting in magenta and this layer is called Tunica Interna, so these are the three fundamental layers.

Then, within this layer you have this one is called this layer, what is see here is called External Elastic Membrane, it varies from arteries and veins, External Elastic Membrane this is one. Then, we have the Internal Elastic Membrane which one is this one, this particularly layer, let me just mark it, this layer is called, this one is called Internal Elastic Membrane.

And then you have this particular thing is called, this green what you see is basically a elastic fiber this is the elastic fiber. And the inner layer out here, his is called endothelium, so this is the broad architecture of all the vessels and the size of these different layers varies.

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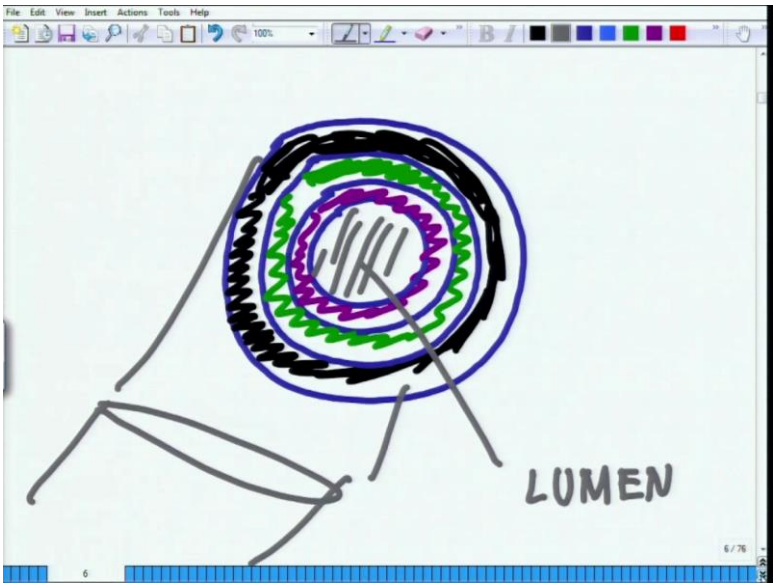


If, I had to redraw this as a cross section, it will look like this, this is the endothelium layer, the inner most layer, this is Tunica Interna, Tunica Media and here Tunica Externa and if I have to give the color code, what I just followed black, green, magenta. So, this is the one, which should be black, completely black and this is in green and this one the inner layer will be in magenta. And this is the hollow cavity and hollow cavity is called this hollow cavity is called lumen and this is the cross sectional view of the vessel, that is how its look like.

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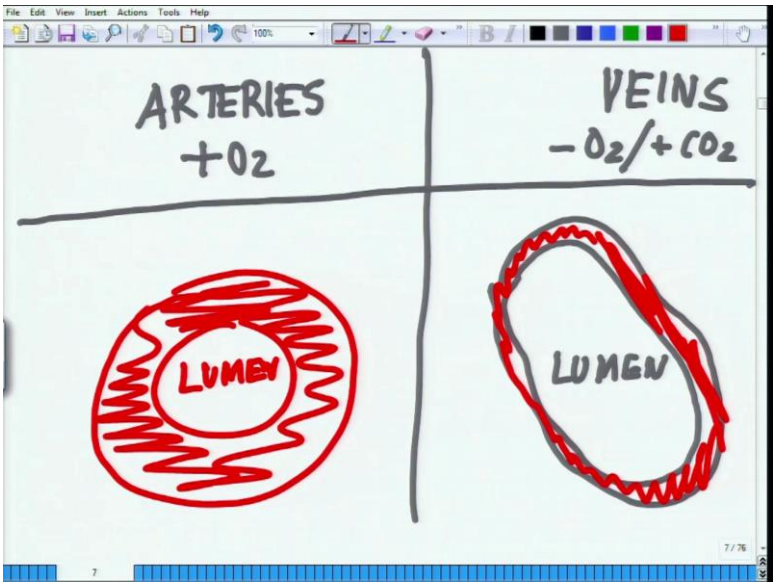


So, based on that, we will be talking about the classification of arteries and the veins, arteries are the one, arteries and veins. So, arteries are the one which are carrying oxygenated blood and these are the one which are carrying deoxygenated blood and reach in C O 2, this is the very, very basic fundamental functional difference between the 2.

Apart from it, there is some structural variation, structural variation wise, if you see the cross section of the veins, it will be more like this, if you look at the cross section. The cross section, the lumen out here and if you look at the lumen of the arteries, they are much smaller. So, here is the lumen, the cross sectional area here is the lumen, look at the let me color it, so that will make more sense, so these are the walls what we talked about, Tunica Indica, Tunica Interna, Tunica Interna, Tunica Media, Tunica Externa. Let me redraw it again for you, this is the lumen and this is and here if you look at the vessel wall that is much more thinner, but lumen is much more bigger and there are reasons and reigns for it.

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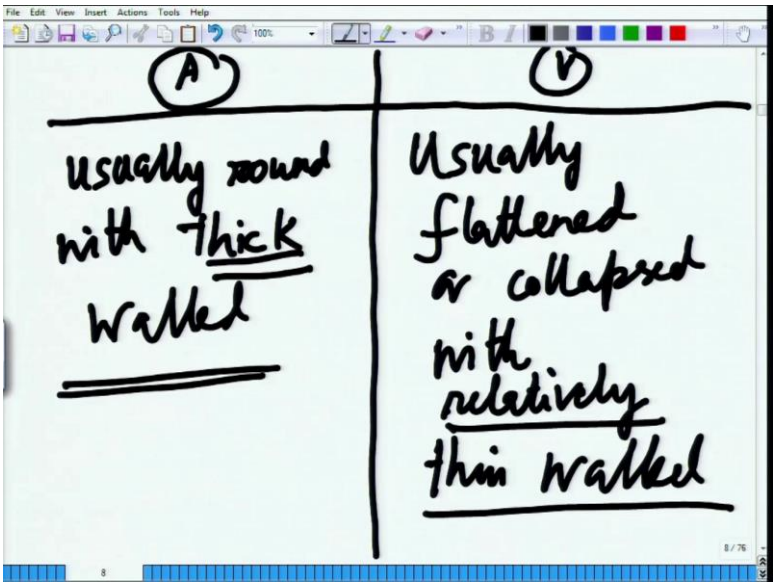


So, before we get into that let us talk, about the further classifications which are there, so I am just indicating arteries with A and veins with V. So, these are usually round with thick walled, as you could see in the previous diagram, I was showing here, there was very, very thick wall. This is very, very important and where is in the case of veins, it is usually flattened or collapsed with a relatively thin walled, this is very, very important relatively thin walled and is much more collapsed to structure.

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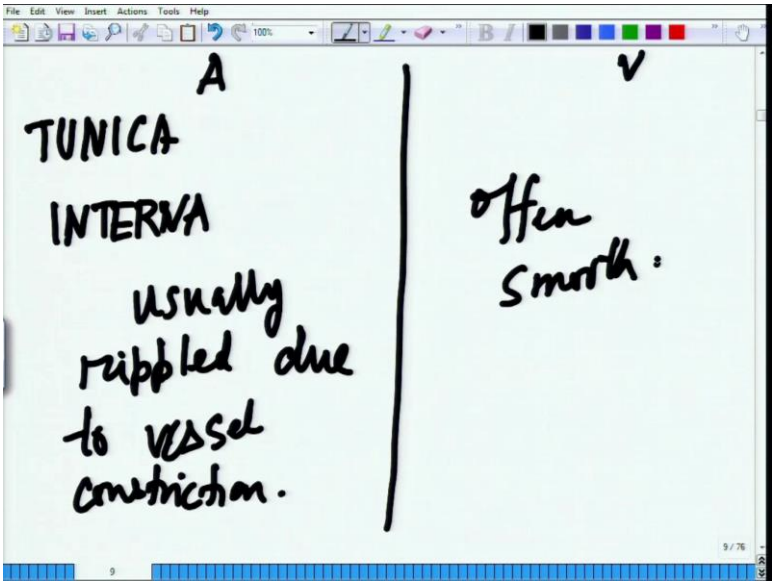

In terms of arteries and the veins, I will talk about the Tunica Interna; Tunica Interna is usually rippled, due to vessel construction, where as in this case Tunica Interna is often smooth.

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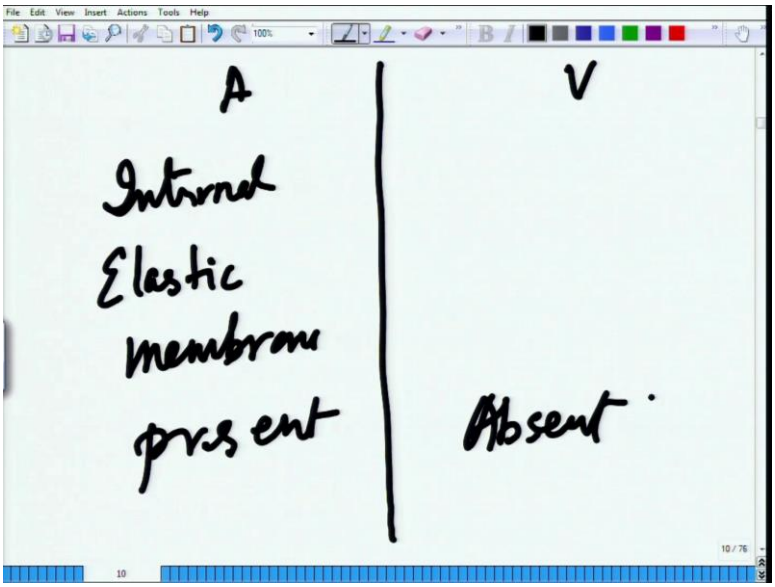


Arteries and the veins, the next classification is in terms of Internal Elastic Membrane is arteries is present, where as the Internal Elastic Membrane is absent in the veins.

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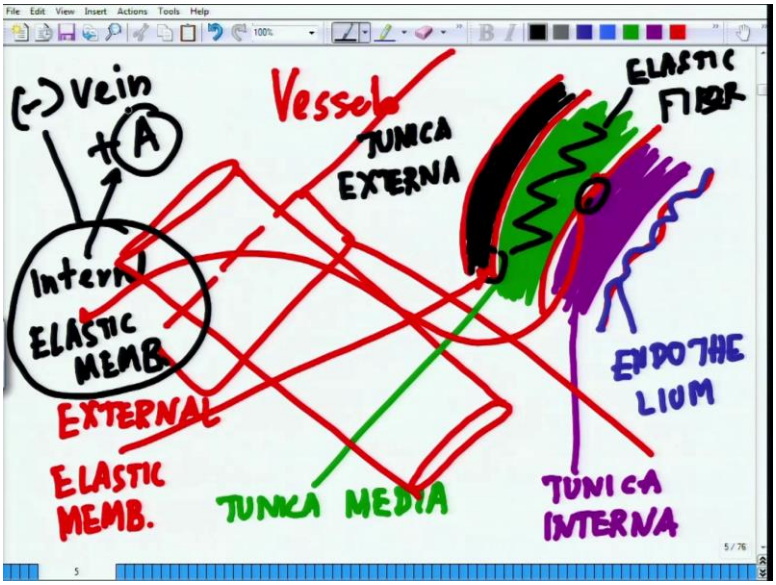


So, if you go back what am talking about is this structures, you see there is an Internal Elastic Membrane out here. So, this one is missing in the veins and this one is present in

the arteries, remember this please, and let me come back to the current slide often smooth, so this is absent here in it.

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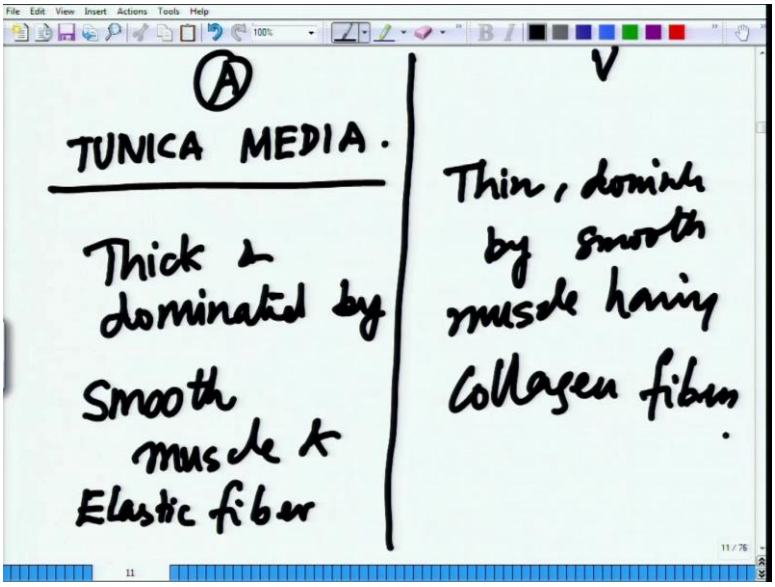


In terms of Tunica Media, arteries and veins and here you have the Tunica Media, thick and this structure is dominated by smooth muscle, this is another third type of muscle, I was telling that, I am going to discuss, while I will be talking about the muscle. Muscle and a lot of elastic fibers reason for these elastic fibers in this because they had to with us withstand a lot of pressure. In terms of Tunica Media in veins, it is thin dominated by smooth muscle, but having collagen fibers.

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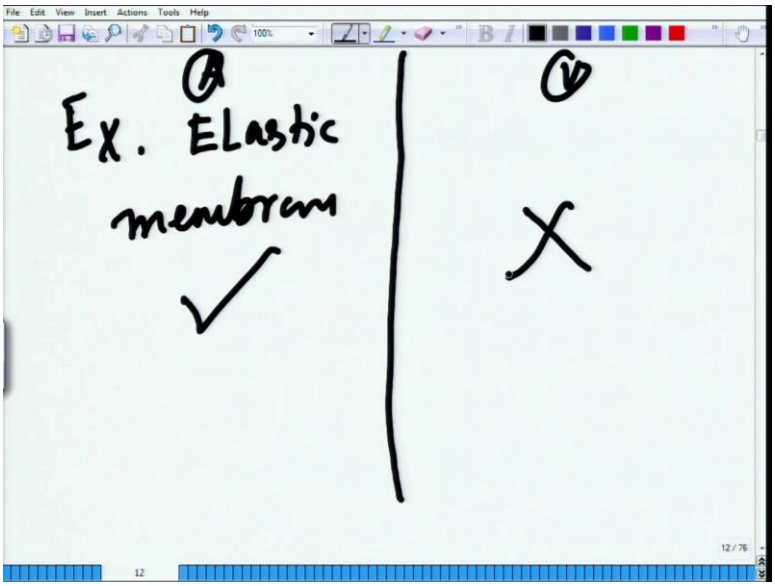


Now, in terms of External Elastic Membrane, this is the arteries and this is the vein External Elastic Membrane is present in this, where as External Elastic Membrane is absent in it.

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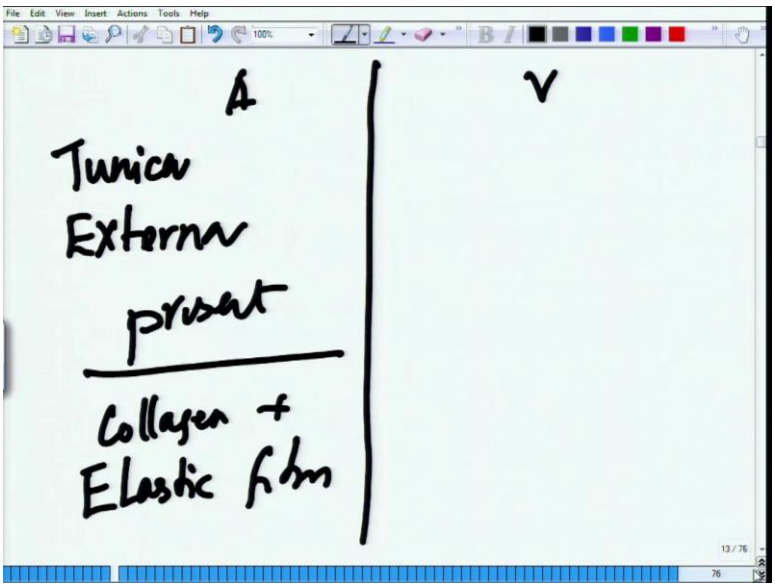


And in terms of arteries and veins in terms of Tunica Externa, it is present lot of collagen plus elastic fibers are there, where as in terms of External Elastic Membrane, it is absent and collagen smooth muscle fibers are present in the Tunica Externa.

So, that is pretty much the overall classification or overall differences between the arteries and the veins, what we are talking about. So, now from here, we will move out that different classification of the arteries.

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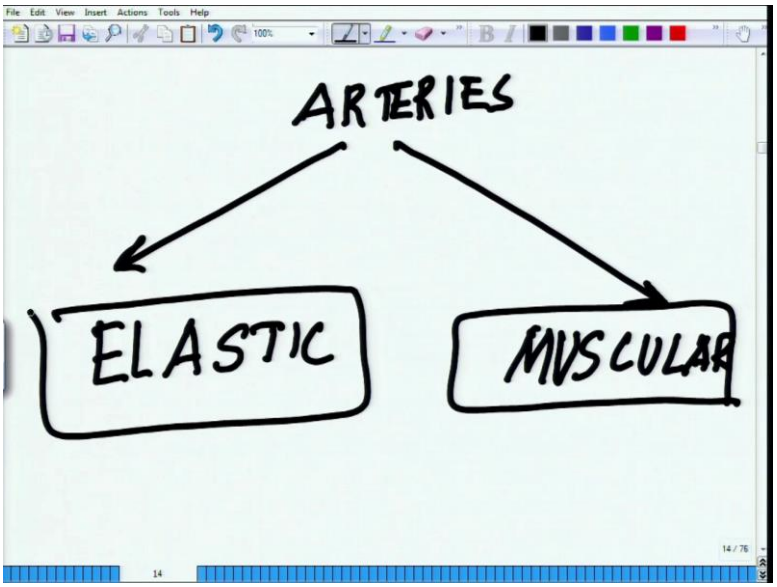


Arteries have different classifications arteries could be elastic as well as muscular, so one thing, I wish to highlight here, as we were talking about the pressure with which the blood is pumped. So, if you recollect very correctly, the pressure with which the left ventricle pumps the blood through the aorta is exceptionally high.

So, in order to withstand that high pressure, all the different structural features about Elasticity, External Elastic Membrane and Internal Elastic Membrane the presence of lot of smooth muscle and much more wrinkled, endothelium in the arteries are the features which help it to withstand that.

Exceptionally high pressure, because as the blood travels away from the heart, as it moves through the arteries and eventually with the capillaries and in the vein, the pressure falls down. So, those vessels which are in the vein which are much more flaccid, you must have seen much more widely, you know cross sectional area they do not need to withstand that high pressure, what an artery has to withstand continuously.

And, this continues till a last moment of your life there is continues flow of blood and these arteries has to withstand that enormous pressure of pumping from the heart and that

is why this structure have been designed in such a way. So, that they on average life span is 70 to 75 years in a developed world or in a developing countries nowadays, then for 75 long years, these vessel should be going to withstand that in almost pressure. That is why, these structural features, what I just now highlighted in terms of Tunica Externa, Tunica Media, Tunica Interna. And, all the External Elastic Membrane, Internal Elastic Membrane is so so very critical.

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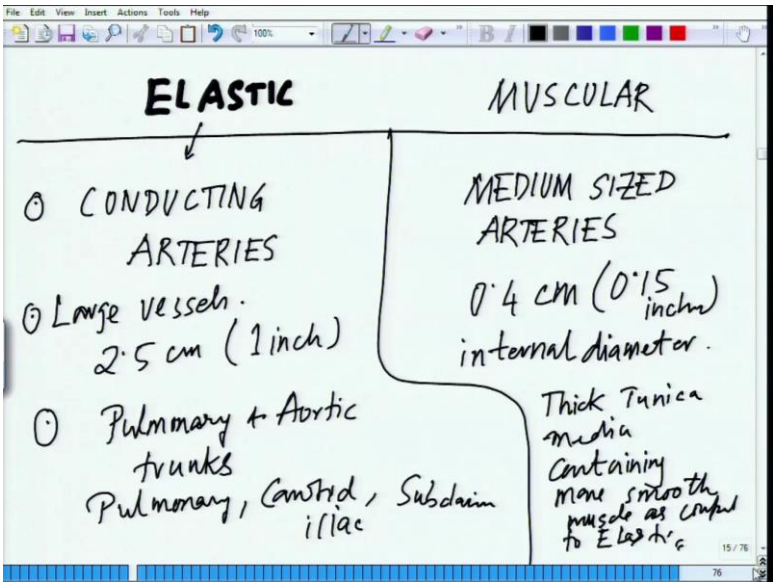


Now, we will talk about the classification of two classes of arteries, which are present in our body. So, what are those, so as I have mentioned, one is called Elastic artery, the other one is called Muscular artery. So, what are the difference between Elastic artery, and Muscular artery, so these elastic arteries are also called Conducting arteries. Whereas, Muscular arteries are called medium sized arteries and there are certain dimensions, which I am going to highlight now.

This medium sized arteries are have a internal diameter, reminded these are all internal diameter, what I am drawing here, 0.4 centimeter or 0.15 inches, this is wherever, I am mentioning in this chapter, these are all internal be careful, these are all internal diameter. And, in terms of conducting vessels these are large vessels and they have a diameter of 2.5 centimeter or approximately 1 inch, these are much larger cross sectional vessels; these are the first two features.

Next features, some of the examples are Pulmonary and Aortic trunk and in case of that includes your Pulmonary artery, Carotid artery, Sub claim artery and you have Iliac artery and likewise. In terms of the Muscular arteries, they have a thick Tunica Media containing contacting more smooth muscles as compared to Elastic arteries.

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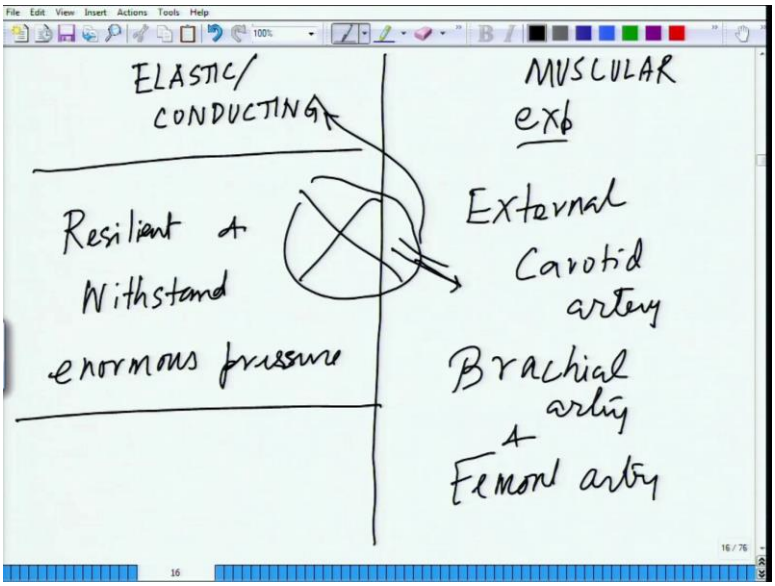


And some of the other features of Elastic or Conducting arteries are there, these are much more resilient and I do not need to again highlight this point and withstand enormous pressure. They can withstand enormous pressure, because these are the ones where just from the heart is that, just immediately from these are the ones, which constitute the Elastic artery and the muscular ones, include some of the examples of the muscular ones are as follows. External Carotid artery, brachial artery, Femoral artery, so these are some of the broad classification of arteries, there is one deceases or one pathological condition, which I wish to bring to your notice.

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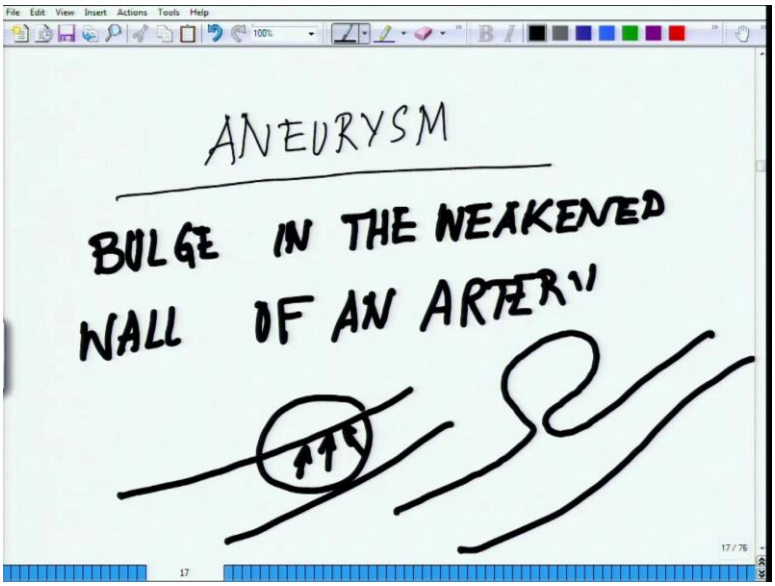


You may hear this or see this somewhere written like this is the word Aneurysm, what exactly is Aneurysm going by the definition of Aneurysm is basically the bulge in the weakened wall of an artery, it is something like this. See for an example, if this is the normal artery, because of some kind of unusual pressure at specific point, what it lead to is you will see at the spot it takes the bulge like this.

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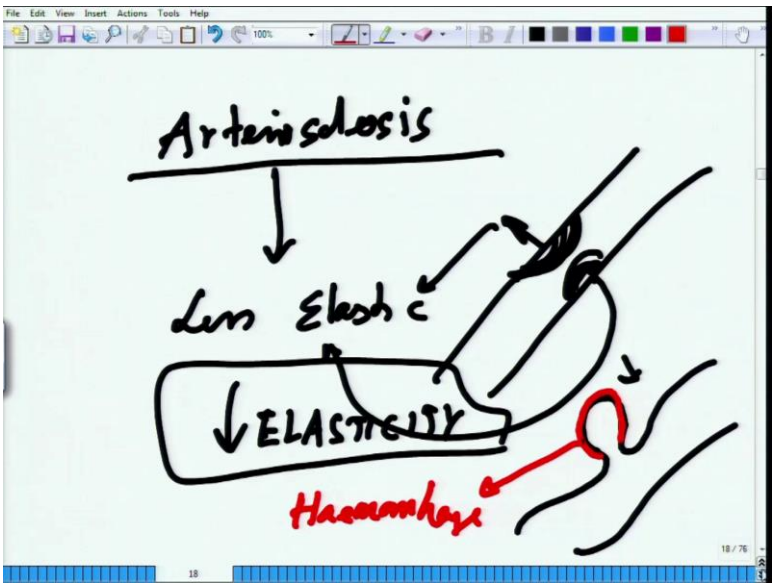


This can happen for multiple reasons and some of reasons in which includes are Arterio Sclerosis which makes the vessel less elastic and during arteries what happens is that,

this is the vessel, where they deposition taking place like this. So, the elasticity of this zone is reduced, there is a decrease in elasticity and eventually what happens in the decrease in the elasticity leads to some kind of a situation like this. At some other point, it bulges out like this, and this particular layer is extremely prone to Hammerage and this becomes extremely challenging, if such Hammerage takes place in the brain.

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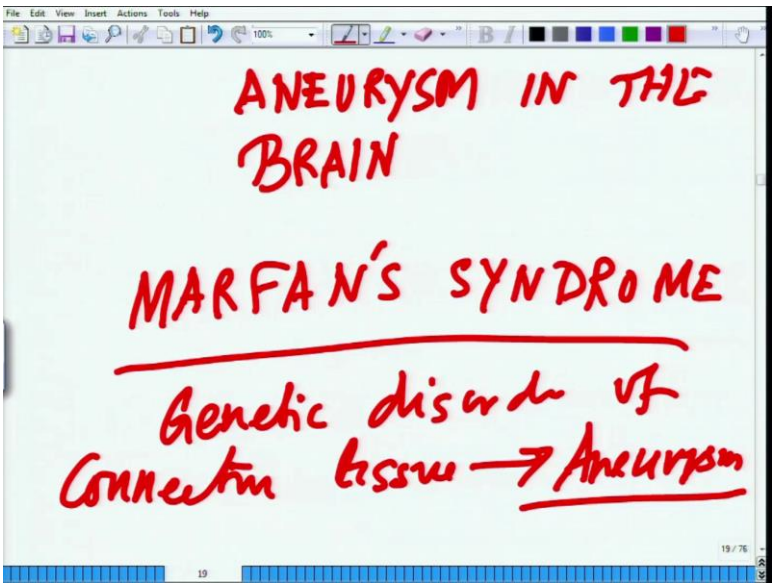


If, Aneurysm in the brain is one of the very fetal situations and there is other situation, genetic situation, if you come back called Marfan's syndrome. Marfan's syndrome is a genetic disorder of connective tissues, which leads to your Aneurysm. So, there are several causes of Aneurysm, most of the Aneurysms are takes place in arteries and because of the weakening of specific part or because of clocking or choking of the arteries at different points.

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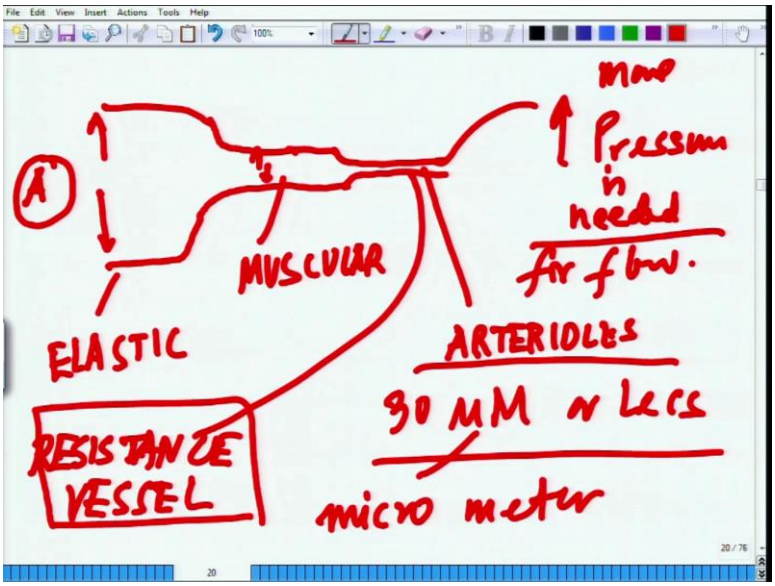


So, now from broad way of arteries, we move on to then next level which is our further, for example, if these are the arteries, this is how the dimensions are changed. From there, we move on to something called the bigger arteries, the smaller arteries and then we move on to something called arterioles, which are much thinner. So, this is the cross section of the first arteries, we talked about and representing by A and these are then medium arteries, which we have already talked about, if these are the elastic ones and these are the muscular ones.

We talked about these muscular arteries and then these are the arterioles, arterioles are have a diameter of 30 internal diameter of 30 micro meter or less 30, this is micro meter be careful, as of now, I was talking about inches and centimeter. So, arterioles have a very less diameter and they are also sometime referred to as resistance vessels, because they pose a lot of resistance in the blood flow resistance vessel and blood needs a lot of pressure. More pressure is needed to make the blood flow through that for flow, this is very essential for you people to understand.

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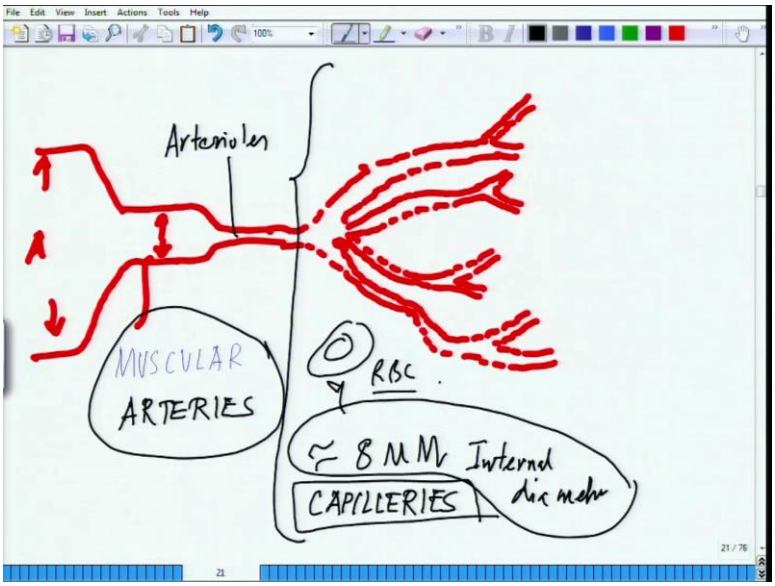


The next level of a vessel for example, if you started like this with the bigger arteries, then we move on to the arterioles and the next thing, what we know is the vessels, where the maximum exchange taking place, those are the capillary vessels and you see in some of the places I am putting it dotted lines. There is a reason for it and I will come to that, why I am putting dotted lines likewise.

So likewise, so this is the part, which you we are talking about major arteries, this is the just change the chip, these are the muscular arteries, so here are the arterioles and here, you are entering the zone of capillaries. Going by the dimension of the capillaries, capillaries are extremely narrow cross section and they are approximately 8 micro meter of internal diameter.

Internal diameter of 8 nano micrometer means, they are almost of the same size of a RBC, the diameter of a RBC red blood cells which would be coming next actually. In the next section, their diameter is almost equivalent to a diameter of single red blood cells. So, this is the zone where all this oxygenated blood which is coming all along.

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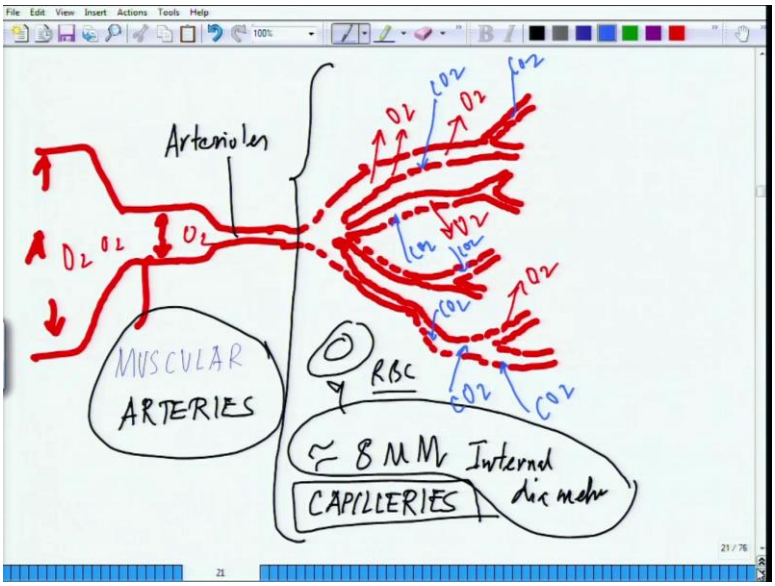


This is all oxygen rich blood, which is travelling through here basically, what happens all the oxygen is being delivered to all the different cells and tissues which are there. So, I am going to talk in depth about this structure and this is where from these cells, the blood picks up the C O 2 carbon dioxide. This is where the C O 2 is getting inside the capillaries and oxygen is taken up by the cells at this point here the C O 2 is getting in which I am putting blue for your understanding. So, now after this what happens is this, so before I get into how the circuit continues is this let us talk about the classification of the capillaries.

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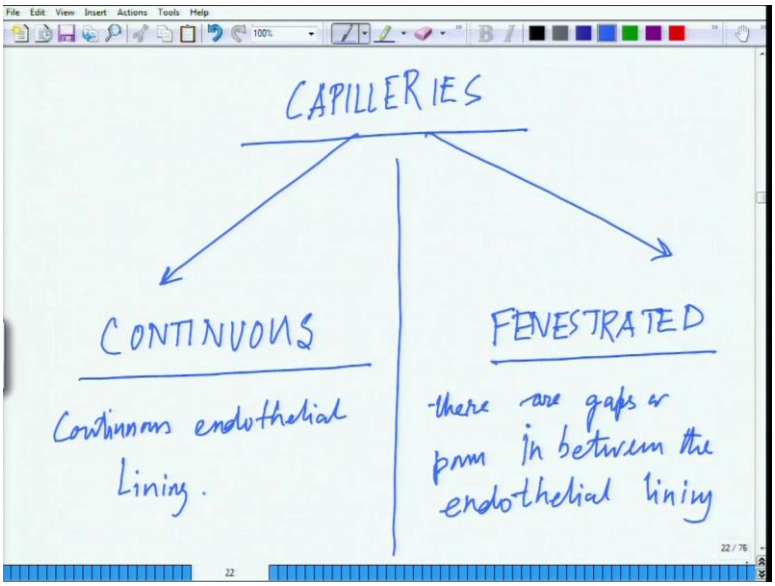

Capillaries, capillaries are classified into two broad heading one is called continues capillaries and other one is called fenestrated capillaries and there is a classification which there are some certain basic differences between the two and that is what you can highlight, what are the basic difference between the two. So, continues capillaries have continues endothelial lining, whereas in a case of fenestrated capillaries, there are gaps or pores in between the endothelial lining.

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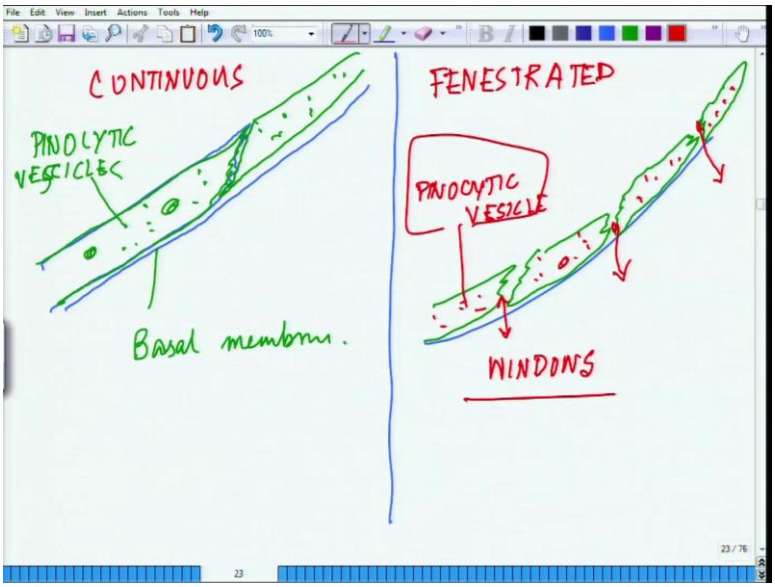


And, if I draw both of them, the continuous capillaries and fenestrated capillaries, they will look like this, if this is the endothelial or the outer layer. So, and these are the endothelial cell, let us may take out another color for your understanding, these are the endothelial cells, they are much more closely packed out here and within them you have these Pinocytic vehicles, pianocyte you remember in the membrane.

We talked about these are the pinocytic vesicles and these are the basal membrane and you see very narrow gaps here, where as in the case of fenestrated capillaries what you see is something like this much bigger gaps likewise. And, these are almost like you know windows through which they exchange could take place much more easily, especially for the bigger molecules windows are fenestration that is what it meant when you talk about fenestrated capillaries.

And, this is where we are talking about the continuous capillaries and here you have the different pinocytic vesicles. So, this is how the fenestrated capillaries and the continuous

capillaries look like, so continuous capillaries indeed promote exchange. But, the fenestrated capillaries with the window like structure promote more and more exchange of the nutrient gases and everything.

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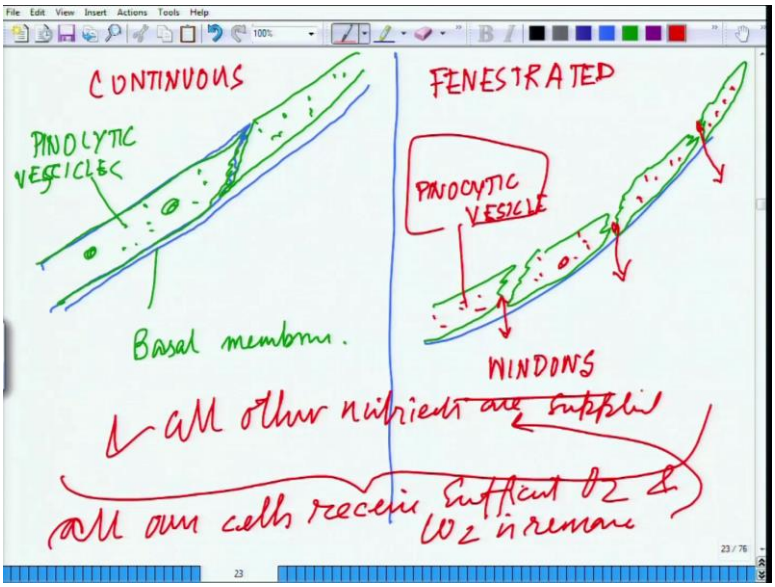


So, this is the feature which ensures that all our cells receive sufficient oxygen and C O 2 is removed and all other nutrients are supplied. Now, coming back to the previous slide where I told you that let me previous to previous slide.

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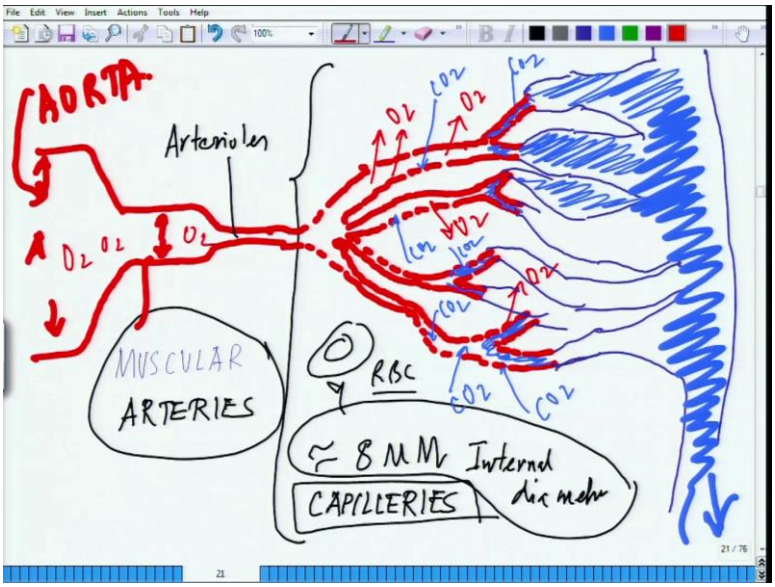

So, now what happens if I put a color code here, so now, the blood is much more blue in other word, what I wanted to indicate is now the blood has more carbon dioxide content in the likewise. As of now the blood burns all kind of you know red which is kind of a sign of all from here what happens is this these are picked up by the next series of vessels I am putting in lightly dark green, which are called venules. These are the venules, I am drawing now, these are the venules which are now coming into play, these venules eventually led to the bigger vessels which are if add them like this with a bigger vessels of veins.

So, these are where your C O 2 rich blood is now travelling through this all C o 2 rich blood. This is all being take taken to the vinacavas and this is what is coming from the aorta. So, after this exchange has taken place all these vein's moves along this veins, but in order to do, so let me go to the next set of classifications out there.

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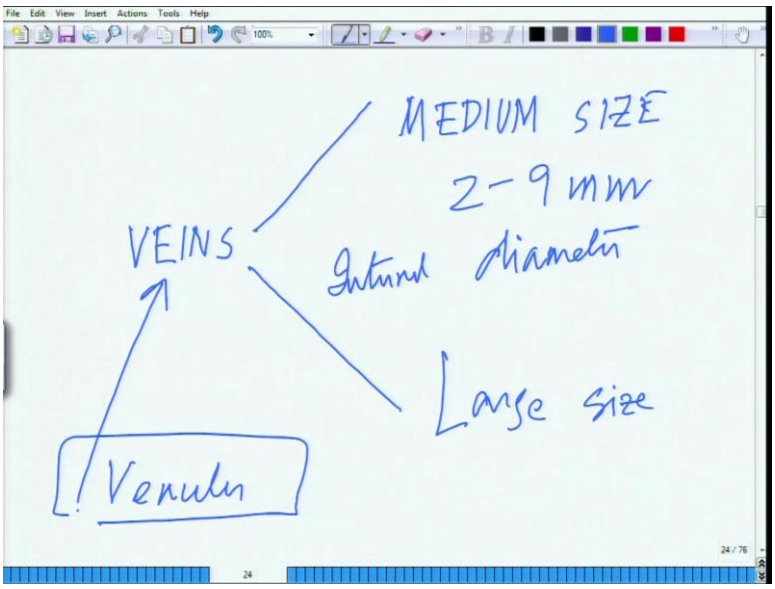


So, the veins could be divided into now, we have classified the arteries, now the veins needed to be divided. They fall under medium size and large size veins, medium size are around 2 to 9 millimeter internal diameter. And then you have larger than that which falls under the large size veins and smaller than veins are the venules.

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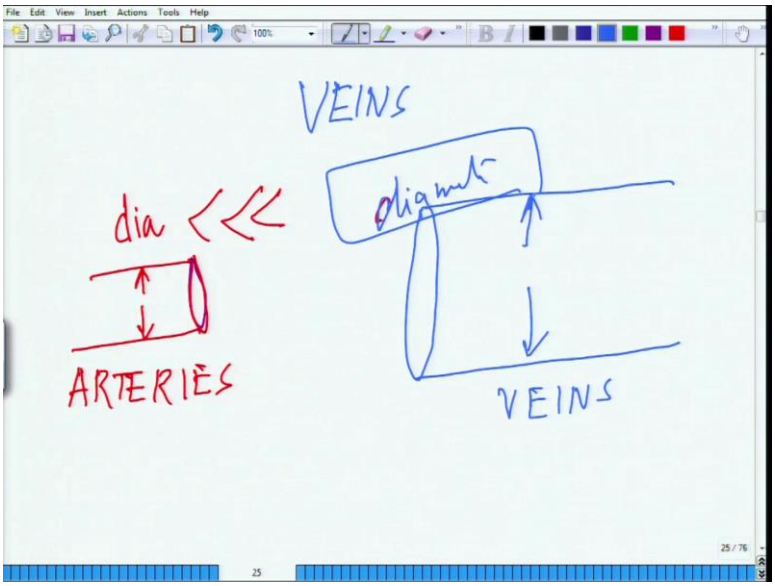


Now there is one interesting aspect of these veins, since by this time it is clear to you that with respect to the arteries and if these are the arteries and these are the veins. Visually, if you look at it they have a much higher cross sectional area, I was showing in pretty much in the first slide, this is the diameter is much smaller as compared to the diameter of the veins.

So, in this situation and by the time the blood reaches the veins, the pressure have of the blood has gone down, because the maximum pressure of the blood is in the arteries. So, whenever we actually measure from the arteries, so when the blood reaches the veins that is the time, when the pressure is very low.

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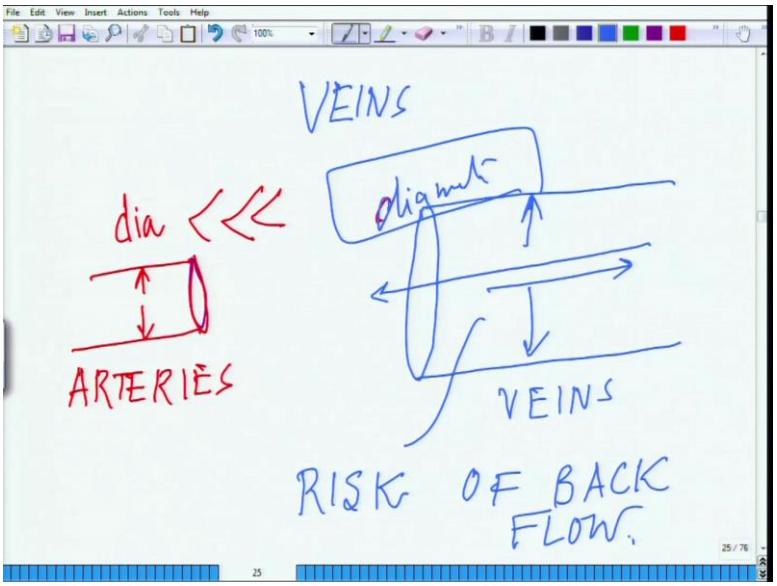


So, there is always a risk the instead of blood flowing in one direction, it may start doing risk of a back flow. So, how nature prevents the back flow of blood in the veins, that is very important.

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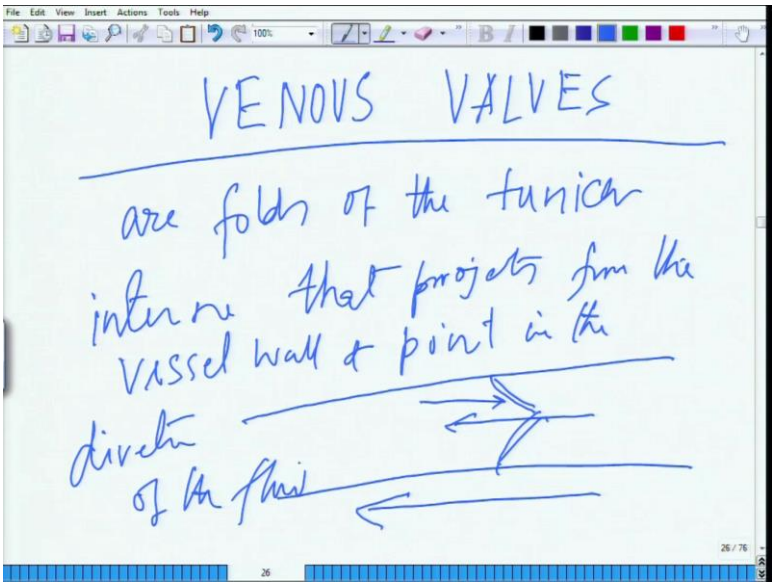


So, that there comes a series of valves which are present only in the veins, these are called venous valves, these are nothing but are folds of the Tunica Interna, this is another. So, venous valves these are basically nothing but are the folds of the Tunica Internal, so what they do the way they fold like that from something like this with their

folding pattern are like this say for example, blood has to flow like this. So, as soon as the blood moves they bend like, this they close, so that the blood cannot really go back in from the direction from where it is coming. So, basically they are the folds of the Tunica Interna, those projects from the vessel wall and point in the direction of the flow.

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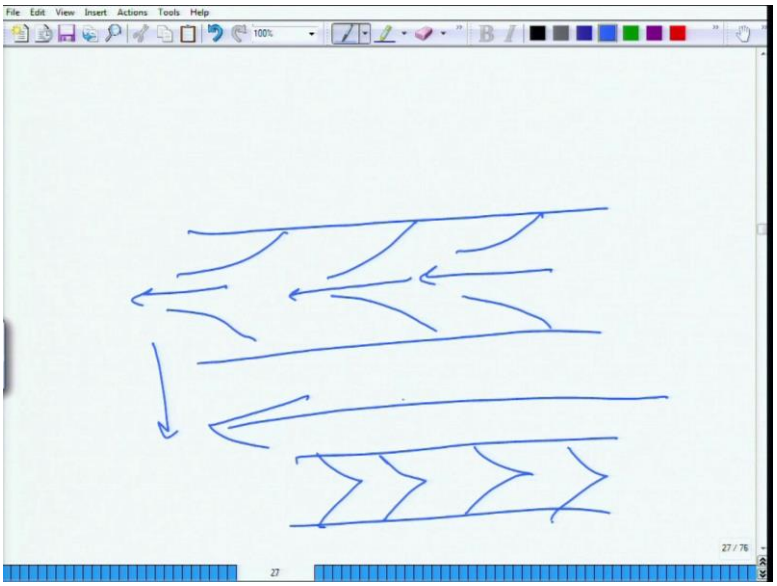

In other word, what does that mean the direction of the flow, so if this is a vessel and the blood are flowing in these directions? So, initially they all look like this, these are the valves and blood is flowing as soon as the blood flows, they closed like this is wrong as soon as the blood flows. This is how it works them closer, so these valves are exceptionally important and they are only present in the veins, they are not present in the arteries.

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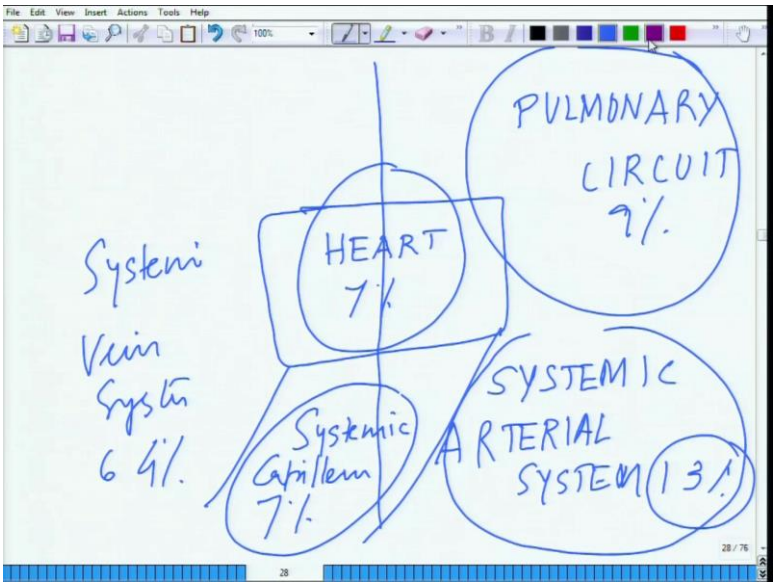


And now what we will be talking about a distribution of the blood at one point of time, all across this whole vessel. So, in the heart, you have out of the total blood, you have 7 percent of the blood in the heart, in the pulmonary circuit; you have 9 percent of the blood. In the systemic arterial system, you have 13 percent of the blood, in the systemic capillaries, you have 7 percent of the blood and in systemic venous system and you have, 64 percent of the blood.

So, this is how the blood is getting distributed if 64 percent, in the systemic venous system in the heart, you have 7 percent, in the systemic capillaries you have 7 percent, in the systemic arterial system you have 13 percent. And, the pulmonary circuits 9 percent, this is the overall distribution of the blood in the body at one point of time at any given instance time.

From here, we will closing this lecture which dealt with anatomy of the arteries and the veins and the capillaries and we talked about the zone, where the exchanges are taking place exchange of gases and exchange of nutrients and other energy rich molecules and how the cells are continuously breath in the capillaries. And we talked about distribution of the blood in the different compartments all the body. From here, we will move on to the cardio vascular physiology, which will part two, which will be our next lecture.

Thank you.