Human Physiology
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Lecture – 16
Hemodynamics

Well, well heart is very important because it pumps the blood and the blood has to flow through the vessels, but heart is just a tool to pump it, but the function of the blood is somewhere removed somewhere on the brain, somewhere on the muscle, somewhere on the skin where the blood has to ultimately deliver its products and the nutrients, the oxygen pick up the carbon dioxide, pick up the excretory products. So, as far as the cardiovascular system is concerned, the real action is happening at the capillaries, where is it happening? At the capillary. So, you need to take the blood, blood from the heart of course, because of the heart ok, but you need to take it to the capillaries. So, so now, another maybe this lecture and a part of next lecture we will try to focus on what is hemodynamics. It is actually a system of pipes ok, and those pipes, but it is not a single pipe - that pipe branches, branches, branches and then the pipe becomes smaller and smaller and then very small and then finally, it forms capillary bed works and then the capillaries get together and then form the venules hello and then the veins go back to the heart ok. And then from the heart to the pulmonary system for oxygenation and come back and it keeps on it keeps on. So, we are going to read about that fluid that has viscosity ok.

So, given the certain volume of system that we have, you have to pump the blood with certain pressure then the walls have to be elastic, some of the walls have to sustain the pressure. Hello those, particularly those blood vessels which are coming from the heart have to sustain the pressure ok. Then the capillaries which are so tiny and just made up of endothelial cells ok, endothelial very tiny, very small we have already seen they just an RBC can barely squeeze through ok. Very simple question, the blood as you will get this point the blood as it enters into the capillary is under the pressure of about 30 mm Hg, 30 mm of mercury 30 mm of mercury. It is not low ok. and what is the size of a capillary, what is the size of a capillary? 6 to 7 microns. 6 to 7 microns ok, thickness of a capillary thickness of a capillary is 1 to 2 microns and there is no there is no other covering because if you put any other covering it will obstruct your passage of movement of goods inside and outside.

So how do you expect such a tiny such a delicate tube to withstand the pressure of 30 mm Hg? Are you getting it? Ok, I am only stating the problem I will give you the answer eventually ok. So these are some of the very exciting questions that will arise when we talk about how the blood is taken to the different organs and let us try to get some insights into the just magical figures just read somebody will read there. Blood - read. Blood supply to the body. In a day or total travels of about.

Wow, what a feat. So if you are a single RBC ok, you are a single RBC you will be travelling so much ok. Now we are going to try to take a look at how much blood at any given moment. So what I am going to do or what the author has done is divided the heart into two parts and put them away for our convenience ok. So at the other end you can see the right heart ok.

So far right heart ok. That is right and that right heart is receiving what blood from everywhere. It will superior vena cava, superior vena cava, inferior vena cava ok. And under average condition how much of blood is being poured how much of blood is being poured into the right heart there can you read for me there. 5 liters. 5 liters how much is it? 5000 ml per minute that is a cardiac output we studied you know in the past two lectures It is about 5000 ml ok. So every minute 5000 ml or 5 liters of blood has entered into the right auricle and from there it has gone into the right ventricle, right ventricle has gone into systole and the blood has gone into the lungs.

So how can you read there how much blood has gone to the lungs same whatever has come and gone. How much is it 500 I made a mistake how much is it? 5000 ml per minute are you ok so far. Just a small question. That pressure is the average pressure ok the right ventricle systole, diastole, systole, diastole, systole, diastole I am going to give you two numbers which I want you to learn by heart – 25 – 8 means what if I do the same experiment wherein I take a tiny pressure transducer and I will leave it in your right ventricle where do I leave it? Right ventricle and the right ventricle is undergoing systole, diastole, systole, diastole ok so what range of pressures are you experiencing? How much? 25 - 8. It is not 120 – 80 mm Hg. How much is it? 25 - 8.

Why do you think 25 - 8 is ok? It is ok because after all you have to send the blood from the from the right ventricle to the lungs and lungs are just on the side. You know on the left and there are two lungs and the blood vessels are extremely large ok. So, you do not need to generate that much of pressure ok. So, you send the blood it comes back how much comes back there how much comes back. So, so I said how much 25 – 8. Whatever it is the average is about how much? No average is about how much? Mean is about 15 mm Hg that is the mean of systolic and diastolic pressure we calculate. It goes to the lungs from the lungs how much how much blood is coming out of the lungs?

Same volume has to come over a period of one minute but what is the pressure, now because the blood has been through the capillaries of the lungs, now it is oxygenated hello. So, what is the blood pressure, which was about 15 average, has fallen to 5 mm Hg.

So, so you measure the blood pressure that is going to the lungs. Mean is 15 mm Hg. You measure the pressure of the blood which is now going back from the lungs to the heart ok same volume what is the pressure? 5 mm Hg. Good. So, now the left heart is receiving about the same amount of blood ok 5000 ml now the left ventricle is a very massive organ. Now let us go back to our transducer and with every systole diastole what is our reading? 120 – 80 mm Hg. The mean is about how much? 104. The mean is about how much? 104.

Are you ok so far? Now with this pressure the blood is now rushing into the aorta, from the aorta it will now branch ok it will branch the aorta will turn one branch this branch will go to the shoulder this branch will go to the neck that branch will go to the neck head etcetera. So, now how much is going to the brain? 700 ml. 700 ml coronary circulation means the wall of the heart hello coronary wall of the heart how much? 2. And kidney is how much? Quick quick kidneys how much? 1000. GI System alimentary canal is how much? 1250 ml.

Skeletal muscle is a very large how much is it? 14 Kg is the weight of a skeleton and then the skin is about how much? 375 ml. But please remember these are very average figures.If you start running then obviously, that skeletal muscle that 1450 may go to 1600, 1700, 1800, but if that goes up then it you have to reduce somewhere. So, the one in the in the GI system may reduce from 1250 to it may go to 1100 or 900.

So, actually what your body is doing, depending on your requirement, it will redirect the blood from the alimentary canal to the skeletal muscles. So, these are on an average. So, as the blood enters into all these organs what is the pressure like? 104. By the time it has been through the capillary network in all these organs now it is heading towards the veins what the blood pressure has fallen to what? Say that again. 4 mmHg.

So, now flowing into the right heart is at about what pressure? 4 mm Hg. 4 it has to be 4 and 3 because we always know that in the atria pressure is very low if you want to pour the blood the pressure better be low ok. So, that the blood can flow in. Now, just as we have absolute numbers here in the next one - we mentioned that cardiac output increases when they are required.

They can go all absolutely. Even in that case just the amount of that going to the other system that is at skeletal muscle falls below which one? No, I will tell you what the all these numbers can go by 2 or 3 times or 4 times ok. Then the body has to decide as to which organ of body has a greater need at the moment, accordingly it will divert the blood to that part. But I forgot to mention one very interesting thing. You remember that the amount of blood that is flowing through the kidney does not vary much, as if it is insulated from the changes because the body wants the kidney to undertake the function of ultrafiltration and must always remain as steady as possible.

Therefore, the volume and the pressure through which the blood is going through the kidney is generally very constant, but do not worry about it I will talk about it when we do the excretory system. For the blood to keep flowing there must be a gradient of pressure. From where to where? From any organ to the other.

Means we must. From the lungs to the left ventricle.

Must be a gradient to be maintained. That 5 mm Hg is there. Because it is already so low 5 mm is ok, because in the in the left auricle, it is it may be 2 or 3 mm Hg. It is still low. The blood vessels are very large and it is continuously being pushed from the blood vessels.

It is maintained at very low pressure. Of course look - the gradient has to be there. If the gradient is not there the fluid will not flow. Laws of physics will not allow the blood to flow. You have to have something you have to have a pressure difference for the fluid to move.

Does it happen that it does not move? It happens. And then we call that position as varicose veins. I will talk about it a little later. Varicose veins remember that word. Varicose veins I will talk about it.

As a result of gravity, the blood tends to accumulate in our veins, particularly in the case of senior citizens. The blood tends to accumulate in the veins and then that is varicose we will talk about it. But otherwise it has to move and the gradient has to be there. This is the same thing only in the earlier one we had absolute figures now the author tells us about the percentages. Are you with me? We are looking at suppose out of the total 100 percent of the blood how much is going to the brain, how much is going to the different organs.

So, let us move on. This slide is interesting, but we have done it. This makes a point that an organ should get amount of blood as it requires. So, we are now taking a very simple view of the entire system where we have the heart, the heart pumps blood into the aorta and then the aorta branches, branches, branches and we will call them and this is the I just make a statement let me see if we can make out. I will say that this part of the system has compliance what do I mean by that? Yeah, when it will expand with every systole, and as the heart goes into diastole the semilunar valve will close, but then this will contract that aorta and it will keep on pushing the blood.

Ok, I will ask you a very simple question. If one of you has the answer to the question that if the tube the aorta is without compliance. I will make it metallic tube ok what will happen? You get the question? This tube there that is coming from the red one which is coming oxygenated blood which is coming from the left ventricle oxygenated blood going to all going to all parts ok. So, it normally going 120 – 80 - that is ok and then every time it is systole ok, and then when the heart goes in diastole, it keeps on flowing the blood. Now, now I am giving you an alternative it is not a great alternative, but I am we are theoretically discussing it what is alternative I am suggesting I am going to replace that tube with a metallic tube what will happen? Yeah. Maybe there will be irregular flow of that actually faster than the pressure is higher. I do not like your word irregular, but the rest of the answer is ok.

You see the heart has gone into systole. So, the blood will come with pressure ok, but then it has gone into diastole ok. Suddenly the blood flow will stop for a while. So, so then the blood will be in jerks the flow will be in jerks. You are looking at the metallic tube every time the heart goes blood, no blood, blood, no blood are you with me ok. Because of the compliance even in the intermediate period between two systole the blood keeps on flowing because of the compliance ok.

And this is also called as pulse pressure. ok. Then the second thing - these blood vessels are having blood under pressure ok. It is going as high as about 120 mm Hg. So, these vessels better have thick walls supplied with large muscles thick muscles. So, it is like you see in chemistry we have you know pressure tubing.

Hello you know what you mean by pressure tubing? You do not know what the pressure tubing in our kitchen gas you know the tube that goes from the cylinder to the stove - it better be thick. Are you getting my point? It better be thick why not? Why not? Because it is carrying gas under pressure ok. Gas under pressure if you use a thin tube it will simply burst ok. So, this is this is more like a pressure tubing you see it has it has to it has to support a huge amount of pressure ok. And then we have branches and then we have arterioles here and then arterioles and then the arterioles will branch which will give rise to capillaries - we will call as meta arterioles.

What do you call it as? Meta-arterioles and just at the point where the meta-arterioles finally, give rise to the capillary bed work just ahead of that you will find tiny smooth muscle sphincter. So, if you can control, if the muscle constricts, the blood will not flow in that particular capillary, hello. So, as if we have a system in which the blood, and we have millions of capillaries, and we have also a system in which you can decide whether your autonomous nervous system or your endocrine nervous system or your blood circulatory system can decide whether I am going to allow the blood to flow this capillary at the moment - yes or no, ok. Yes or no. If it is yes let the blood to go otherwise stop it, ok. It is very relevant. I will come to that a little later.

Every cell in your body has to be either next to a capillary or next to a cell and then a capillary and next to a cell and a capillary, but that is all. So, every cell is either 2 or 3 cells away from a capillary. You get it. It is not possible that a capillary is here - every cell must have a capillary in very close - just 2 3 cells away. Then secondly you see, you have the capillary - what are they lined with - endothelial cells single cell flat and then those cells may also have tiny gaps ok through which the blood under pressure - maybe 30, 20, 20, 25 or 10 mm Hg pressure. I will tell you I will talk about that. Now that you know plasma oozes out what did I say? Plasma oozes out.

Plasma oozes out from where from the endothelial cells of the capillaries ok. What is the length of a capillary? What is the length of this capillary from here to here from here to here length of the capillary is at the most 1 mm, maybe less, maybe half maybe 3 quarters of 1 mm, tiny. So, it is a tiny tube diameter 7 microns the length is less than 1 mm. Do not miss those figures. Are you with me? An RBC takes less than a second to pass through it – it zips through – takes less than a second. So, during that second whatever business it wants to do it has to do it has to accomplish that business within 1 second ok which means what? Releasing substances, absorbing substances, giving oxygen, taking carbon dioxide, taking ammonia, nutrients, secretory substances everything, but I am not talking about that. Some of the plasma substances yes plasma, but devoid of large proteins like albumin and globulin they are large molecules they cannot come out of the capillary because they are too large and also because of the charge on them they cannot come out. The smaller molecules like glucose etcetera - they easily come out and some of them are treated in a very special manner. How they are treated I will tell you. There is a mechanism for that. I will talk to you, but some of it can get into what you call as lymph what you call as what? Lymph. Lymph contains WBCs. It does not contain RBCs therefore, we also call it as white blood, but the right word is lymph. The lymph has a different system and this tells us how - so look at this diagram and tell me where is the where does the lymph formation take place? Look at the diagram and tell me where? Capillaries where? Capillaries where say that loudly where? At the level of capillaries, the liquid part the plasma which is devoid of large proteins, it starts flowing outside and we will call it as lymph. And then there is a different pathway and it goes again back to the circulatory system and this is important because I will talk about it again this is important because it contributes to the formation of extracellular fluid that forms the environment of every cell. Hello? Every cell has an environment that is extracellular fluid we have seen you know the how much of sodium potassium how much sodium inside sodium we have done all that. That is in the extracellular fluid, extracellular fluid comes from where? You got the message - extracellular ok.

Alright, so then so the blood will flow into the capillaries and into the post-capillary venules and then venules and then they will merge and they will go. Should the wall of the vein be as thick and strong as that of the artery? No. No, no you do not need because the blood pressure there is 5 mm or 6 mm or 2 mm - you do not need to ok. So let us with this background let us move on. Yes. So you mentioned that sphincter determines which capillary gets the flow and that is determined by the autonomous nervous system. We talk about it.

So sphincters are generally, they are they are governed by the product secreted by the cells. There are local secretions like adenosine is one of them I will talk about it is - a very familiar molecule. It has a very interesting role. They have adenosine receptors, hold on, we will come to that. So you can see a graphic of a artery there ok. And that artery as can you see there are three layers - outer layer tunica externa, tunica media and tunica interna - tunica means a coat ok. The tunica intima is or the innermost coat is also nothing, but endothelium. Now endothelial cells are very special. Just do not think that they just form a tube and they allow the blood to pass - no they are very special because - in the previous lecture, I have mentioned about a very small molecule, I said it has a profound role in - it very tiny molecule you remember that name of that molecule I will give one more clue. I have …. very good who said that very good I am so happy very happy. Yesterday I spoke about what - say that again - nitric oxide ok. It is a signaling molecule it is a neurotransmitter - it is a gaseous neurotransmitter. We will talk about it - Nobel prize 1991. Great molecule it is gas ok which is the easiest source to have it you tell me nitroglycerin what is it nitroglycerin? Ok, but that is from outside ok. We have our own source of generating nitric oxide and that source is nothing, but endothelial cells in your system. The innermost layer of your blood vessels, ok, are capable of generating the nitric oxide. Can somebody tell me what is the logic in providing nitric oxides from endothelial cells - as the source for nitric oxide. Yesterday we discussed the function, what function did we discuss the blood vessel relaxation. Why would you give a nitroglycerin tablet to a patient of angina pectoris why - because if coronary circulation is not normal, so you want the coronaries to relax therefore, you are giving NO so what is the function of NO to relax the smooth vessels to relax the blood vessels - why will they relax - because the smooth muscles will relax.

So, can you, in that diagram can you see the smooth muscles. They are thick smooth muscles so that is what I meant by pressure tubing. So, do you find so much pressure tubing in the veins look at the image on the right ok. And then on the right something interesting you find. Can you see the valves ok can you see the valves. So our veins have valves, our arteries do not have valves - putting valves in the arteries would be a nuisance. Ok. They will obstruct the flow of blood, but in the vein particularly in your legs. Ok. When the aim of the heart is to make sure that the blood flows through your legs and it travels against the gravity, it goes back to the heart ok. So, whereas the gravity tries to pull it down our circulatory system wants to take it up, ok. And just to make sure that the blood still flows therefore, our when a system is provided with what provided with valves, ok. And so, so just compare the thickness of those with the middle layer, which is smooth muscles, oh very important the middle layer can you see that red middle layer there, that layer of smooth muscles - have we discussed the smooth muscles in this class no no. I will discuss it when I talk about the alimentary canal. I will have full lecture on the physiology of the smooth muscle good, but right now just enough to tell you that we have smooth muscle lining into the tunica what you call as media and I just want you to compare. So, whereas that tube is very good to handle pressure, this tube is actually very good to handle a lot of volume, it can expand you know it can stretch, the veins can stretch ok. Arteries cannot stretch much, it is a bad idea because if you they have transport blood under high pressure.

Now, as a result of that - get this point - as a result of that at any given moment in that vessel which means in arterial system ok you have about 14, 15, 16, 17 percent of your blood volume is less volume but the pressure is high whereas, in the case of venous system the amount of blood they will have may be about 70, 80 percent of the total blood - is located at any given moment in the veins, but the pressure is low - are you with me. Now it is very interesting. The veins have far more volume. So, actually your venous system is your storehouse of blood - are you with me - it is your storehouse of the blood ok. And it is under low pressure as we have already seen - it is very interesting do not miss the point. I am talking about the sympathetic nerve supply which comes from where - in the case of heart - we have seen that it comes from T 1, T 2, T 3, T 4 hello, but actually our heart is not the only organ - we have other organs also like the stomach is the alimentary canal is there is they also. So, the sympathetic nerve supply comes from T 1, T 2, T 3, T 4, T 5, T 6, T 7, T 8, T 9, T 11, T 12 are you with me L 1, L 2 let us see this is the all the sympathetic supply will come from the spinal cord. At that level - you absorbed the point - hello you got it now ok. Now, they will give rise to pre ganglionic fiber and then and then somewhere here and then the post ganglionic fiber and the post ganglionic fiber sympathetic is going to release what neurotransmitter.

Say that again. Say that again. Nor epinephrine. Nor epinephrine ok and that norepinephrine lot of that supply will go to all the different kinds of blood vessels and in the blood vessels they will supply the smooth muscles. So, whether you are in a artery or whether you are in a vein if you are artery you have a thick layer of smooth muscles if it is a vein it is a thin layer of smooth muscles, but whether you are here or there all those smooth muscles have a very rich supply of what post ganglionic sympathetic fibers. And they are going to release norepinephrine are you ok so far. Now in front of you is a very interesting do not miss - for example the blood vessel that is running through your alimentary canal - what do I mean by that - take the intestine and take a blood vessel that is going to the intestine and then that blood vessel it is showing in two different states. So that is the blood vessel there and that blood vessel is getting a nerve supply can you see that nerve supply there, there is a nerve supply in both there is a nerve supply ok. And now and it is a post-ganglionic sympathetic nerve supply so you know that nerve supply is releasing what neurotransmitter.

Norepinephrine, and who is receiving the norepinephrine. Smooth muscle. Do the smooth muscles have receptors for nor epinephrine. Yes what kind of? That is interesting point I will come to that. Now on the nerve can you see those vertical lines are there on the upper image also and the lower image also. Yes or no? can you see the vertical lines on the two images. What is the difference? The upper one the frequency is more ok that is one difference and the second difference do you find a similarity or differences between the diameter of the two tubes what are the differences? The lower one the diameter is higher - now can you put two and two together and can somebody tell me what is happening? High frequency signaling means whenever the sympathetic nervous system is stimulated it is sending more action potential per unit time it is releasing more nor epinephrine which will bring about the constriction of the vessel and if the vessel is constricting then what will happen to the blood flow through the alimentary canal? What? What? Go down what? It will go down because the blood vessels are what? Constricting ok.

Now, you see I will go back to my very favorite example - for you it ,ay not a great idea, but I like the example. You being chased by a dog ok. So, suddenly your muscle blood requirement has gone up are you with me? Now, the second point, - I want to step back and make another point when we talked about heart - we talked about innervation by the parasympathetic supply over the vagus hello and sympathetic supply over the T1, T2, T3, T4. So, what we emphasize is the dual supply and whereas the sympathetic nervous system will stimulate the heart, the vagus or the parasympathetic will inhibit the heart we got it.

Do not form the impression that the dual innervation is universal. No, no, no heart has dual supply yes, but this vessel does not have a double blood. It only has sympathetic supply. Hello are you with me? So, do not be under the impression that every organ must have no, no. It is the autonomous nervous system that will have, in the case of heart, dual supply. Yes in the case of this blood vessel which goes which is going through the alimentary canal it has no parasympathetic blood supply. It has only sympathetic it is only sympathetic. And how d,oes it manage to control it is very simple. When your body wants to constrict it t will excite the sympathetic nervous system ok constrict it when you want to relax then reduce the input of the sympathetic nervous system then automatically it will relax are you with me. So, just by the activity of sympathetic nervous system going up or down you can exactly, very well regulate the diameter of the blood vessel and regulate the flow of the blood through any particular organ you got the point. Hello everybody. Hello. hello