Human Physiology
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Hello everyone, welcome to another new class in human physiology. In this class, we will discuss blood capillaries and also see how blood capillary microcirculation happens in the body. So, let us stick with it. So, what different content will be covered in this class? We will discuss different types of blood vessels; we will see what a capillary is, and we will look at microcirculation. So, what are the different types of blood vessels that are present in our body? In the last few classes, we have already discussed that we have arteries and veins, which you all know, right? But we also have various types, like microcapillaries. So, apart from microcapillaries, what are the other different types of blood vessels? For example, we have elastic conducting arteries, muscular distributing arteries, and then we have arterioles, venules, and veins.

So basically, in our body, there are a lot of micro blood vessels, almost more than 40 billion of those micro blood vessels that are called capillaries. These capillaries are very thin and approximately 5 to 10 micrometers in diameter. And if you see their structure, there are like two distinct kinds of cell layers. The inside part you will see is mostly an endothelial cell layer, and the outside part you will see is like an epithelial cell layer.

And just like the blood flows through the arteries and veins, eventually blood passes through these microcapillaries inside the microcapillary bed. And the goal is eventually to distribute the blood to the smallest corners of our body, to all the cells and tissues, distributing the oxygen and, even after cellular respiration and metabolic activity, the carbon dioxide, and supplying the carbon dioxide to the lungs for further oxygenation. So, in terms of capillaries, we all know what capillary movement is, right? So, capillary attraction, or capillarity, is the ability of a liquid to flow in very narrow spaces without any assistance, and basically, this movement of the fluid can happen against the gravitational force. So, as you can see, if you put a small glass capillary inside of water, what we will see is that the water will slowly rise. And this rise of water, along with this capillary-diameter wall, is completely without any assistance of any kind of force, and this is against the gravitational force in the opposite direction.

And the capillary movement of any fluid basically depends on two properties: one is the addition of this liquid to the wall, and the other is the cohesion of the molecules together. And the capillary movement will only happen if the addition of the liquid to the capillary wall is greater than the cohesion of the liquid molecules. And in cases where the cohesion of the liquid molecules is greater than the adhesion, the liquid may fall and may not rise. So, as you can see, this is capillary movement, and these things also happen in our human body. What are the different types of capillaries that are present in our body? Basically, there are three types of capillaries.

One is continuous. The continuous one mostly does not have any type of porosity or perforations, and basically, as you can understand, it only allows extremely small molecules to pass through. And where you can see this type of continuous capillary, you can observe them in muscle, in skin, in fat, and even in nerve tissue. Then there is the second class of capillaries, which is called fenestrated. They have small pores, and you can mostly see them in the intestines, kidneys, or endocrine glands.

Lastly, there are the sinusoidal or discontinuous types of capillaries. They have large open pores. These are large enough to allow blood cells to pass through, and mostly this type of sinusoidal or discontinuous capillaries can be seen inside bone marrow, lymph nodes, and the spleen, and this is also termed the leakiest of all capillaries. So, you can understand that in cases of fenestrated capillaries, what you will see are large gaps and pores between the cell layers. And these pores will basically allow the passage of different molecules, and the blood cells can also pass through these pores.

Then there are different other classes of blood vessels that we will quickly go through; for example, in our body, we have elastic conducting arteries. One of the prime examples is the aorta, and its diameter is about 1 to 1.5 centimeters. Then we have muscular distributing arteries; they mostly distribute blood to specific organs, and their diameter is in the range of around 6 millimeters. Then we have arterioles, which mostly feed the capillary bed, and these are like small vessels nearly 35 micrometers in diameter, and they have smooth muscles called pericapillary sphincters.

So, you can see this pericapillary sphincter; these are smooth muscles or muscle cells that basically control the blood flow when the blood actually comes inside this capillary. So, using the movement of these finter muscle cells, blood flow can be controlled. And then, as we just discussed, we have capillaries, which number around 40 billion in our body, and their diameter is about 8 to 10 micrometers. And if you see, the inside of the capillary is like an endothelial cell layer, and the outside is an epithelial cell layer. And sometimes beside the capillary, it also has these pericytes or smooth muscle cells.

It is basically like a connective tissue layer, which is also called the basal lamina. And they are mostly designed for the exchange of gases, the exchange of different types of waste, and hormones. Then there are venules, which are mostly about 20 micrometers in diameter, and they basically form large veins. As we all know, they are a low-pressure system with a pressure of 5 to 10 millimeters of mercury, a much larger type of lumen, and they contain about 70 percent of the blood volume. So, now once we discuss different types of blood vessels and capillaries, we have to discuss microcirculation and how it happens.

So, let us see how microcirculation happens and eventually how blood goes from an arteriole to a venule. So, if you look on the very left side, we have this terminal arteriole here, and on the right side, you can see we have this post-capillary venule. So, what happens is that basically arterial blood comes here from the terminal, and then you see a lot of capillary beds right. So, basically this can also be called true capillaries. And here, in between the arteriole and the venule, it forms an anastomosis.

So, basically, this is the arteriovenous anastomosis, right? Or this is also called a vascular shunt. So, combining the arteriole, the terminal arteriole, and the post-capillary venule, what does it form? Arteriole-venule anastomosis, or it can also be called a vascular shunt. So once the blood comes here, you can see that eventually blood will flow inside this true capillary, and this is called a capillary bed because there are thousands and thousands of capillaries present. This is also called a capillary bed, and eventually blood will flow through this capillary bed and come to the venous side, and eventually blood will come out from this post-capillary venule. So, this is basically the circulation pattern of how blood first comes into the arterioles, exchanges through these small capillaries, and eventually goes out from the post-capillary venule.

So, this part, this part, this red part is also called the meta arteriole, and then this part, this venule side, is also called the thoroughfare channel. These are just for your nomenclature. Now, once we understood how blood flows from the arteriole to the venule across the capillary bed, we should also discuss a little bit about the different types of blood pressure that actually contribute to the blood flow in or out. So, let us see, in this picture we mostly have two sides, right? So, this side is, for example, the arteriole side, right? This side is the arteriole side and this side is the venule side, right? So, what different types of blood pressure will be generated here? Let us see one by one. So, the first one, the blood is going from the arterial side and eventually it is coming to this capillary bed, right? So, this blood is flowing under a certain pressure; this is called hydrostatic pressure.

So, this hydrostatic pressure of the arterial side will be about 35 millimeters of mercury pressure. So, what we just said is that blood is coming from inside the arterial side and eventually it enters the capillary bed. This flow of blood is actually under a certain pressure called hydrostatic pressure, and the pressure on the arterial side would be around 35 millimeters of mercury. Then let us consider that blood carries a lot of substances, like blood proteins, right? So, basically on this atrial side, there will be a lot of concentrated protein, for example, albumin, right? Hemoglobin. So, a lot of blood protein will be there on this capillary side.

On the contrary, the outside, which is the interstitial side, right, because this side is mostly like the interstitial tissue side where we have the interstitial fluid. Here we do not have too much albumin or blood protein because most of the proteins are retained through the blood and eventually go via the circulation. So, here the blood protein concentration is low. Now, you know what osmosis is. Osmosis basically involves cases where water flows from a low concentration of ions or molecules to a high concentration of proteins.

So, from this side, we will also have another pressure, which is like the osmotic pressure, which would be about 25 millimeters of mercury. So, what pressure are we discussing? One is the blood flowing, which generates hydrostatic pressure, right? That will be about 35 millimeters of mercury. And then there is another osmotic pressure where mostly the water will try to come inside, and this osmotic pressure will be around 25 to 26 millimeters of mercury. On the other side, this interstitial fluid may also create a very minimal amount of hydrostatic pressure, which is roughly about 0 millimeters of mercury pressure, which actually means that there is not a significant hydrostatic pressure generated by the interstitial fluid. Similarly, the osmotic pressure on this side is also about 1 millimeter of mercury pressure.

So, that is basically what is coming out, right? So, basically, there is also another osmotic pressure, which is about 1 millimeter of mercury pressure. So, then let us calculate what the different pressures are basically happening in cases of the atrial side. So, which pressures are coming out? One is the hydrostatic pressure, which is about 35 millimeters of Hg, and then there is a little bit of tissue osmotic pressure, which is about 1 millimeter of Hg. And then, which pressure is going in? The tissue osmotic pressure, which is caused by the water flow of about 25 millimeters of mercury, and the hydrostatic pressure generated by the interstitial fluid, which is very minimal at about 0 millimeters, are considered. So, can you now calculate how much the net filtration pressure would be on the arterial side? So, 35 plus 1, which is 36.

And then minus 25 plus 0, which is 25. So, roughly, the net filtration pressure, or the net flow pressure, basically on the RTL side, would be about 11 millimeters of mercury, and what is the direction of this? The direction of this, like the flow of pressure, would be outside. So, basically, the overall net filtration pressure is directed outward in cases of the arterial side. Let us see what happens, basically, in cases of the venous side. In cases of the venous side, a lot of blood has already been removed or exchanged for different types of proteins, such as albumins.

Here the hydrostatic pressure drops a little bit. So, here the hydrostatic pressure on the venous side becomes about 17 millimeters of Hg. The osmotic pressure inside is still the same, about 1 millimeter Hg. So, what are the outside forces then? Now it dropped the hydrostatic pressure, which is about 17 millimeters of Hg, and the osmotic pressure, which is about 1 millimeter of Hg. And then the pressures we are basically dealing with are cosmetic pressure due to genetics, which is influenced by the interstitial fluid inside, which is about 25 millimeters of Hg, and the hydrostatic pressure of the interstitial fluid, which is pushing the fluid inside, which is basically 0.

So, now, if you can calculate the net flow pressure on the venule side, how much will it be? So, 17 plus 1, which is about 18 millimeters, hg minus 25. So, basically, the net filtration pressure on the venule side would be about 7 millimeters of mercury pressure. So, these are millimeters. Sorry for the typo. So, basically, about 7 minus 7 millimeters of mercury pressure, and what is the direction for this? This is the direction for this pressure is the in.

So, basically, on the arterial side, the net filtration pressure is positive 11 millimeters of mercury, and on the venous side, or the venule side, the net flow pressure is about minus 7 millimeters of mercury, which is the net pressure, okay? Let us now see the different conditions in the physiological or abnormal state, and let us try to understand how the capillaries and the surrounding tissues in the capillary area are affected. Now, for example, in cases of glomerular nephritis or nephrotic syndrome, what will happen is that it will lose a lot of protein or albumin in the urine. So, basically, the osmotic pressure would go down. So, what we are basically saying is that, for example, let us consider that this capillary bed is present near the kidney and due to some kidney disorder or kidney disease like glomerulonephritis, a lot of albumin protein, like excess albumin protein, is coming out, right. So, excess albumin protein is coming out.

Now, what will basically happen is that if excess albumin is coming out, this osmotic pressure gradient will drop, right? Because here, now albumin will eventually increase in the interstitial fluid, and here the albumin protein will decrease. If this osmotic gradient goes down or is disturbed, the water will not be able to come inside. So, that means the water molecule or aqueous molecule eventually gets retained in the interstitial fluid. And if it retains inside this interstitial fluid, like a lot of water molecules, if it retains, right? If it gets retained in this interstitial fluid because of the irregularities, like the osmotic pressure of the interstitial fluid, this gradient will get disturbed, right? So, what will happen and why this will happen is that albumin basically leaches out, and the concentration goes high in this interstitial fluid area, while the albumin concentration on the capillary side or the blood side is basically going down. So, this osmotic gradient will fall, and basically, it will retain a lot of water in the interstitial fluid, and this condition is called edema.

So, in that case, a lot of water accumulation will happen in the tissue. In cases of, for example, cancer, you can see abnormal formation of tumor mass happening, and that can basically create occlusion in the lymphatic vessel. So, in that case, what can happen is that this lymphatic drainage will not occur, and a lot of backflow will start. In the same way, it can cause edema, fluid accumulation, or swelling. So, these are some of the abnormalities in that case; tissue fluid can eventually accumulate and can basically cause a situation called edema.

Now, before we do some more conditions like this, the combination of this arteriole or venule is also, as we have already called it, an anastomosis, right? So, basically, if the arteriole and the venule branch together and mix, they are called an anastomosis. And why they are physiologically relevant, let's see. For example, this is a classic case where venous anastomosis happened, right? You can see that this is the cephalic venous area and this is the basilic venous area. So, let's consider that the blood is moving in this direction, and all of a sudden it finds a big clot or thrombus. For example, all of a sudden it finds a big thrombus or clot formation at this end.

So what will happen? The blood will not be able to come out, right? So, blood will not be able to come out. But because of this venous anastomosis, it has more branches. So even though the blood flow can get restricted at this end, blood can eventually come to this side and go out from the other side. So this is the utility of the anastomosis where, in cases of delicate organs, in the case of formation of a blood clot or thrombus, if the blood cannot come out, what will happen? The pressure will build up, the blood pressure will increase and eventually that will completely kind of destroy the blood capillaries because capillaries are very soft and delicate and they can completely rupture. In that case, blood loss can occur, and it can also cause a condition called ischemia and stroke.

So, this type of anastomosis can be mostly like three types. One we already discussed, which is like the arteriovenous anastomosis, right? In the last slide, we already discussed how the arteriole side and venous side mixed or branched together. And it formed like a capillary bed. So that is like a classical example of the arteriovenous anastomosis. Apart from that, two veins can create an anastomosis, which is called venous anastomosis, and multiple arteries can also create an anastomosis condition.

A classic example is the circle of Willis, which is present in our brain. However, this type of arterial anastomosis can also be seen in cases such as the heart and joints. So, you can see this beautiful circle of Willis where so many arterioles basically have a kind of network of connections, and in case of any clot formation that may hamper the blood flow, the blood can eventually go out from the other side of this circle of Willis or from another artery. So, the advantage of the anastomosis is that in cases where blood flow is restricted, the blood pressure will increase, and this anastomosis will help the blood to move from another side using the blood pressure, thereby maintaining proper blood flow.

So, hopefully, you understood. Let's see some more cases we'll discuss, such as what happens in cases of certain physiological conditions and how the capillaries and their surrounding cells react. So, for example, this is during exercise. What we do like is that our body cells produce a lot of energy. So, during the cellular respiration process, it generates a lot of carbon dioxide, and this carbon dioxide can react with water and eventually form carbonic acid, which can dissociate into protons. So, what excess will we see, like excess carbon dioxide after metabolic or cellular respiration, and excess proton ions? So, these will go high, and we will also see a lot of lactic acid, right? So, we will also see a lot of lactic acid.

So, what will happen to all these, like excess lactic acid, excess carbon dioxide, and excess H plus, is that this will basically relax or inhibit the surroundings, like skeletal and smooth muscles. So, what I just said, like what this lactic acid or excess H plus or excess C will do, is that this will basically inhibit the function of this skeletal muscle, and if it inhibits the function of the skeletal muscle, the muscle cells along with the blood vessels will be relaxed. So what will happen is that the smooth muscle cells will relax along with the blood vessels. So once the blood vessel relaxes, what we call the condition is vasodilation, right? As the muscle cells and the blood vessels get relaxed, it is called vasodilation. And as you can understand, when blood vessels get dilated, it will basically help in terms of increasing blood flow.

So it will increase blood flow, and blood can carry a lot of nutrients and oxygen to it. So in this way, during the exercise, this excess CO_2, excess lactic acid, and excess protons can kind of inhibit muscle functions and dilate the blood vessels. Causing or resulting in a vasodilation situation with higher blood flow that can carry more oxygen and nutrients for maintaining a proper physiological condition. In the case of a brain, there is a significant blood vessel network and blanching because the brain needs a lot of nutrients and oxygen all the time. And the pressure because this blood gets carried out at a continuous pressure, which is like in the brain, is called mean arterial pressure or MAP.

So in cases like this, mean arterial pressure, or MAP, goes higher, what will happen? Because the brain is a very delicate tissue with millions and millions of neurons, high blood pressure can cause the capillaries in the brain to completely rupture. And that will cause blood leakage, fluid accumulation, or edema, resulting in a swollen condition of the brain, and eventually, it can cause damage to the brain cells and neurons. So, in case of certain disease conditions, if the MAP or mean arterial pressure in the brain goes high, what it will do is basically create a condition like vasoconstriction. So, basically it will try to constrict the surrounding cells, like the blood in the blood vessels, to create a vasoconstricted kind of condition that would reduce blood flow. Right, because if the blood pressure is too high, it can damage the surrounding cells and tissue if the blood flow is significant.

So, in this way, if MAP, or the mean arterial pressure, goes high, eventually the capillaries will be constricted to reduce the blood flow to minimize the damage. In the same way, in cases where mean arterial pressure goes down, what will happen is that the blood will not be able to flow properly to the brain, and if the blood is not able to flow properly to the brain, one will feel dizzy because the proper oxygen and nutrients will not be carried inside; so in that case, the body will try to create a condition of vasodilation, causing the normal blood vessels to become dilated, which will ease blood flow and make it easier to carry oxygen and nutrients. So, in cases of mean arterial pressure when it goes high, blood vessels will constrict, and it will reduce blood flow. In cases where mean arterial pressure goes down, it will vasodilate the blood vessels, causing an increase in blood flow. So, these are certain physiological situations in which the capillaries and their surrounding cells and the blood vessels basically get adjusted.

In the case of lung, let us see what happens. For example, if we have a lung infection here, let us think that it damages certain alveolar cells in this area. And if it happens, these lung cells will have less capacity or a lack of capacity to become saturated with oxygen, right? And for that reason, the partial pressure of oxygen will fall. So, now, let us consider this side; we have a healthy kind of functional lung cells where the proper partial pressure of oxygen is maintained. But in these cases, there is this disease condition where the partial pressure of oxygen is not properly maintained. So, how will the capillaries kind of get adjusted to it? So, let us assume that blood capillaries are going everywhere inside the blood, right? You remember, as we said, that almost 10 percent of the total blood is distributed inside our lungs, and because of that, the lungs can also be termed a blood reservoir.

So, can you tell me, for example, about one capillary that is going here and then the other capillary that is going there? Now, in this case, if the blood goes—basically, the blood goes in this area—what will happen? This area is already diseased or damaged, so even if blood comes here, it will not be able to get saturated with oxygen, right? Because the partial pressure of oxygen has already fallen here, the body will not actually direct blood flow here. So, basically what the body will do is constrict this area's blood vessels. So, basically, they will create vasoconstriction, and in this way, the body will prevent the blood flow in this direction because the body does not want to waste any time sending some of the blood to this diseased area, as there would not be proper blood oxygen consumption in this area. So in this way, they will constrict the area, and maybe on this side, they will vasodilate the area; they will vasodilate the area, which means more and more blood will eventually be able to come into the lung, which side is healthier because here the partial pressure of oxygen is being maintained properly, and in rapid succession, the blood will be able to get saturated with oxygen. So, in this way, in cases of bacterial infections, tumor formation, pneumonia, or any chronic pulmonary disorder, the surrounding capillaries will adjust in a way that maintains proper oxygen delivery.

Hopefully, you understand. In the last example, let's consider this as our gastrointestinal tract and this as our skin, right? So, mostly these are not our important organs. Of course, these are important organs, but these are not critical organs like the heart, lungs, or brain. So, they can have a slower blood flow rate inside the GIT or the skin compared to other critical organs. So, for example, during the exercise situation, what we need is a lot of rapid perfusion of oxygen and a lot of rapid delivery of nutrients. So, what the blood capillaries or blood vessels near the GIT and skin will do is that they will constrict; they will create a condition called vasoconstriction.

In this way, they will reduce the blood flow to this unimportant organ, such as the gastrointestinal tract and skin. So, once the vasoconstrict these areas, eventually blood will flow more towards the other important areas like the brain, lungs, and muscles; in this way, they will maintain proper blood oxygen saturation. And this is a disease condition; sometimes what can happen, like in cases of AV malformation, is that this capillary bed is missing, which means the arteriole is directly connected to the venule side, and in this case, if the capillary bed is completely missing, the blood flow is abnormal and the blood pressure can be too high because it is directly mixing from the arterial side to the venous side. So, this type of effect or disorder can be congenital; it can be seen in rare cases, but it can still be observed. In those cases, embolism therapy can be done to reduce blood flow and blood pressure.

So there is a lot of medical significance to the blood capillary. Some of them we have already discussed. You can do this self-like study, especially for certain terminology like skin benching. Then you can discuss; you can kind of study the capillary refill. A lot of diseases exist where capillary malformation and macular degeneration can occur. Also, you know, there is a birthmark, which is nothing but a port wine stain or a dilated capillary.

So you can read, you can do self-studies about some of this medical terminology. So, hopefully you enjoyed the class on blood capillaries. Let us think about it. How does the structure of capillaries differ from arteries and veins? How do blood pressure and osmotic pressure regulate the movement of fluids in and out of the capillaries? You may also refer to this book.

If you have any questions, please send your questions by email. Also, you can discuss with us in the live sessions. Hopefully, you are enjoying the human physiology classes. Let us meet with another new class soon. Thank you.