Human Physiology
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Lecture – 04
Physiology of muscle - Part : 1

Yesterday we did something about a very interesting concept what we learnt as homeostasis. And we tried to understand as to how all compassing it is. And any physiological process we may try to understand and interpret in the light of how homeostasis is being organized in our body. And how it ensures that the internal environment is kept as constant as possible, in spite of continuous perturbations.

Now we will move on and we will talk about the muscle physiology. We know that there are, why do we need muscles? because we have to interact with the environment and we need to move. See this is mechanical, see we have to move in the world. So the nature has provided us with a wonderful system which we call as the muscle physiology. And let us try to learn something about it. And again we have done this in the school. We have three different kinds of muscles, so now there are the special types. Basically at the heart of everything there is actin and myosin, remember it is actin and myosin and the sliding of the two filaments on one another, but their histological structures are pretty unique to each organ. Therefore I will call it as a cardiac muscle, I will call it as a skeletal, skeletal and I will call it as the smooth muscle. I will talk about smooth muscle when we go to the digestive system, I will talk about the cardiac muscle when we talk about the heart eventually. Then we have the skeletal muscle about which we are going to focus here and now.

So we are going to talk about the skeletal muscle. If you look at the skeletal muscle, even cardiac muscle you find that there are very clear striations on that, can you see that dark and light bands there, hello, can you see those. Before that let me show you this interesting image. This is just an animation, okay, little animation makes the things interesting, okay. So somebody is flexing the muscle, if I can use that phrase. Somebody is flexing the muscle, not a great idea. So there is, you will find that the muscles are inserted there on the pectoral girdle, on the pectoral girdle and the other end of the muscle is on the radial ulna here, okay.

And as the muscle contracts you pull up the hand, okay and as you pull, the pulling up action is called the flexor muscle, so those flexor muscles and when the flexor muscle contracts at the same time the other, the muscle on the other side has to relax, are you with me? So we will call this as, so when this muscle contracts I can extend my hand, okay. And this is called as extensor. Now don't you think that this is so simple and so elementary and so basic, but in 1920 Sherrington got Nobel Prize for this discovery, are you not stunned? For a very simple discovery that you have a muscle, when this muscle contract the other guy has to relax and other way, now very simple, very simple, 1920 Nobel Prize Sherrington, okay. So that is what Sherrington told us about, so let us move on. So this is the motor function and when you, so you take a tiny piece of muscle, skeletal muscle from anywhere and you stain it, don't stain it, don't care, just put it under the microscope and you will find that there is clear cut, there are cut fibers and then you can see the clear cut striations, dark and light and dark and light and dark and light and therefore the name has come, striated muscle. Now this muscle we will also call as, we can also call as voluntary muscle. Why do you call it as voluntary muscle? Because I can move it at my will, okay, this is in stark contrast, this is in stark contrast with certain muscles of my body which I don't control. Okay, like the peristaltic movement of the alimentary canal, okay, like the contraction of the gallbladder so that the bile is released. Okay, you don't control it. Okay, it happens within the internal regulatory systems, about which we will talk sometime later.

But right now we are focused on the skeletal muscle, a thing that you can control is the voluntary muscle. Okay, so voluntary muscles are the striated muscles. And, oh this is an interesting image. Just look at it. So here we have the skeletal muscle has to be anchored on one bone and the other end has to be on the other bone. So that when the contracts you can have the functioning of a joint, okay. Now here we have, there you have again the muscles of your upper arm, again you can see the extensor and the flexor there. Are you with me so far, hello, great. So then I will take a tiny part, so this is the bone, on the bone this muscle is inserted and I have this muscle bundle going that way And if I take a transverse section, I find that there are several, I can count 1, 2, 3, 4, I can very clearly see some bundles there. Can you see some bundles there - each bundle I will call as a fascicle, what do I call it as? Fascicle. So there are series of fascicles. And then I will take a closer look at a fascicle and from a fascicle I will go on to a single pinkish body. Can you see there are pinkish bodies everywhere? Now I will take this, and this is still a diagrammatic - to find out what that pinkish tiny body is - I will take a histological section, transverse section through the muscle. And now I will stain it and put it under a microscope. I find that those pinkish bodies, body, body, body all over. So this is just one fascicle zoomed in here and in each fascicle I can see those pinkish bodies, each pinkish body is a transverse section of a muscle fiber. When I say muscle fiber I mean muscle cell and when I say muscle cell I mean muscle fiber. The two words are used interchangeably. Is the concept clear, muscle cell is same as muscle fiber. So what we are going to concentrate on is the muscle fiber. Now if you see very carefully around this muscle fiber can you see there is plenty of whitish tissue. Okay, it is everywhere, everywhere, the whitish tissue is everywhere. Whitish tissue is connective tissue, okay and connective tissue makes a thin sheet around the muscle cell - it is extremely long, muscle cell can be several inches or few inches. It can be very small, or can be very long depending on location.

So, and the beauty is here. Look muscle is an amazing organ for a simple reason. That there is an amazing geometry, geometry of what? Geometry of fibrils, the way the fibrils are organized, at a precise point, when I say this precise, this fibril and this fibril and when I say that these two fibrils are three nanometers apart, they better be three nanometers apart, not only here, but all along the length. If I say that they the precision in the geometry is the absolute beauty of any skeletal muscle. Have I emphasized my point? Geometry. Why I am using the word geometry repeatedly? I will come to that very shortly. But before that, let us see the dark bands and the light bands and a textbook tells us that the dark band we will call it as A band, A band and I band, very funny words, why A and I. So what you do is you take a muscle tissue.

You will find that there are these alternate bands, there is a light band, dark band, light band, dark band, light band. I will impinge light in this direction. And then the light passes through the dark band, follow my story, when the light passes through the dark band, it shows a certain refractive index. Are you with me so far? Now I send the beam of light in this direction right angle to the previous one and I get refractive index and I find that this refractive index is different from the first one. So depending on the direction in which you send a beam of light through the dark band, refractive index is different. This is Anisotropic band, A band.

In the case of I band, no matter in which direction I throw a beam of light, refractive index is same, therefore I band. Hello, so you should know why A band is I band and why, so what does it stand for? Please read here. Isotropic and anisotropic depending on the properties. Alright, alright, alright, alright.

Now look at this image. This is real biological structure. We are looking at the length of the fiber. We have taken extremely thin section, we put it under transmission electron microscope and I find that yeah, what I said so far is really there, there is a dark band and there is a light band, there is a dark band and the light band and I can go from all along the length, all along the length of the muscle from one end to another. And I will get alternate light and dark bands. And now I probe a little bit, little deeper because I have an electron microscope image in front of me and I find that at the center of the light band, center of the light band, very interesting, there is a very dark line. So actually, actually the light band is not uniformly light.

There is a very thin dark band and people call it as either as Z disc or Z membrane or Z line. Three different names mean absolutely the same. What did I say? Z disc? Okay. So what is this Z then? It is made up of, I will tell you a little later, okay, but right now I will give you - it is extremely rich in a protein called as Desmin. What do you call it as? Desmin.

It is rich in- I will talk more about Desmin. So this is, so this, okay. And then this is the I band and when I stretch, I have a long fiber and I go from one end to another end. A little careful observation reveals to me that actually it is repetition of, so if I go from Z disc to Z disc from here to here, okay, so there is a half of the light band, then a dark band full and half of the light band, again half of the light band full dark. So I find that there is a unit and the unit starts from Z membrane, it goes to another Z membrane and I will call this as sarcomere. What do I call it as? Sarcomere. So what is my sarcomere? If I walk along the length of a muscle from one end to another end, okay, I come across repetition of units and each unit is a sarcomere and how do I define my unit? Z membrane to Z membrane, Z membrane to Z membrane, Z membrane to Z membrane, are you with me? So what is the sarcomere, its unit along the length and it is bound by Z membrane to Z membrane and it is sarcomere.

Is that very well taken? Okay. But you can take light band and black band together and call it as a unit. You can. They are also repeating. Absolutely, absolutely, very good. If you just base your statement on this observation, it is absolutely correct. He is saying that why do I take only this as a unit, I can be at the center of a dark band, I have a line here, I have a line here also. Can you use that line? Okay, I will give you the name. That line is called a M line. What is it called as? M line.

It is called as M line because it is at the center of the sarcomere. Are you with me so far? Okay, but he is right. He can say that, well, I can say this is a unit. So M line to M line, M line to M line, M line, I can take that unit also and why not? Not because when you look at the whole thing in terms of function, which I will tell you in another 5 to 10 minutes, you will realize that - in terms of function sarcomere works as a unit. Okay, and not M line. Okay, and these details I will reveal to you in another half a dozen slides. Okay, so anatomically you can do that but functionally it makes more sense to take sarcomere as a unit. Oh, don't forget, there is plenty of sarcoplasm and in the sarcoplasm you have for supply of food material, there are plenty of glycogen, granules and fat droplets are there. And of course there are a huge number of mitochondria. You have to have. Okay, you cannot do without supply of energy.

So this is just to emphasize and there are mitochondria and there are blood vessels and there are nerves. Okay, I mean they are all passing through the connective tissue and they will terminate on the plasma membrane of a muscle cell and how it functions, we will see a little later.

Thank you.