Animal Physiology
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Lecture - 18
Stretch Reflex Phenomena

Welcome back to the 3rd lecture of our 4th week where we are, and the first 2 lectures of this week we talked about the forces velocity tension relationship in the different kind of muscle fibre, we talked about the fast twitch fibre, we talked about the slow twitch fibre, we talked about the isometric contraction.

If you remember of the muscle fibres and most of these measurements are in terms of sarcomere lengths. We can of course do it in whole muscle also and one point which I highlighted is that force generation is a function of the myosin subtypes which are present there. So, a fast twitch fibre will have different myosin subtype as compared to a slow twitch fibre and where we concluded the second lecture, there are two terminologies which I introduced the intrafusal fibre and the extrafusal fibre. I told you that we will continue further with the intrafusal fibre because that is where the border between nervous system and the muscular system is very hazy.

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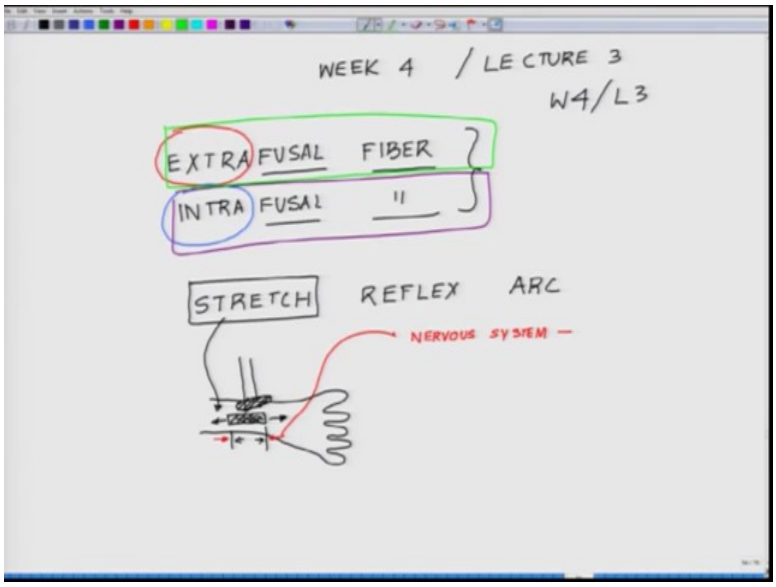

So, keep these two words in mind before we resume further. So, let us get back on the slides. So, we are into week 4 and lecture 3, W4 L3. So, keep these two words in mind extrafusal fibre and intrafusal fibre. Whatever I underline is the common thing, the rest is these two different aspects extra and intra, keep this in mind and let us talk about a situation. I am standing here right, say for example: I get a hit like this, right. I would really do not feel the pain that much unless I have been hit very badly continuously.

What happens in a boxing ring, where somebody gets a hit or you must have seen in a boxing ring or somewhere some movie somebody gets a like you know the muscle kind of you know bend and it comes back to its original position, right. This thing happens every moment of our life. The muscles get distorted and come back to its original position. Very transiently it gets distorted. You must have seen you know somebody hits you like this and the muscle comes back to its original position like it does not remain like this only, fine. How that happens? It is a very simple question. I am asking how a muscle which gets a mechanical hit like this comes back to its original position. So, if you have to break this problem, then from a very engineering perspective if you try to break this problem, I have to break this problem in a logical way.

So, say for example, this is a system and it can come back to its original position. Suppose imagine if this would have been a flexible system. So, I bend it and it comes back. So, it should have some form of a memory. It can come back, it means the muscle which I am hitting comes back to its original position should have some form of a memory or some form of a signal which say for example, I distort the muscle like this, I hit it like this or I hit it like this, it hit, it like this. There is a distortion in the muscle. So, it means as soon as I remove the force, if I keep on holding it, it would remain like, otherwise the very moment the force is released, it comes back to its original position and this not an elastic phenomena by the way. There is something part of it maybe, but its not the whole thing, something much more in depth is hidden. What is it?

So, all our muscles have sensing elements which could sense the change in length which is happening. When there is a force which is generated or which has been exposed to it, is it making sense what I am trying to tell you? So, whenever you are hitting somebody like this, you know you hit me like this, there is a force which is generated on this

muscle and as soon as I release the force, it comes back to its original position. So, all our muscle have some specific sensors which now mark my word very carefully now which could sense the change in length of the fibre and this is not sarcomere. Sarcomere is where the length is changing. There is something else which could sense it and as soon as that senses it, it sends spiral message all the way to the nervous system and the nervous system then sends a message to the muscle to come back to its original position. Let me repeat it.

So, there is a signal, a force, a muscle exposed to a force. Of course, muscle gets stretched yet within the muscle, there are some very unique elements. Those elements sense the change in length, but this does not remain silent. They sense this signal through a wire which is part of through a chord which is part of the nervous system to the spinal cord or some time to the brain mostly to the spinal cord and the information gets processed, and there is a relay route which brings it back and tells the muscle you come back to your original position.

So, what is happening? First there is a force generated on the muscle that leads to the stretching of the muscle, find this stretch, muscle comes back to its original position by a nervous route because the neurons tells the muscle you have to come back to your original position, you have to relax back to your original position. There is a stretch, there is a contraction, and there is something you have to come back. This is one of the most fundamental circuits at the interface of nervous system and muscular system and this circuit is called stretch reflex arc. It is a reflex action stretch like a twitch. It is a reflex action that is stretch reflex arc. So, if you divide the word, there is an stretch in the muscle. So, here I am having, so I pick up an area out here in the muscle. So, I apply a force within hammer.

So, once I apply the force, if this is the area of my choice what I have picked up, there is a change in length, there is a stretch here. This is the stretch. This stretch is brought back to its original shape like this and there is an involvement of the nervous system in bringing it back and when we open up this problem, we open up this problem at different level. So, first level of opening up this problem is.

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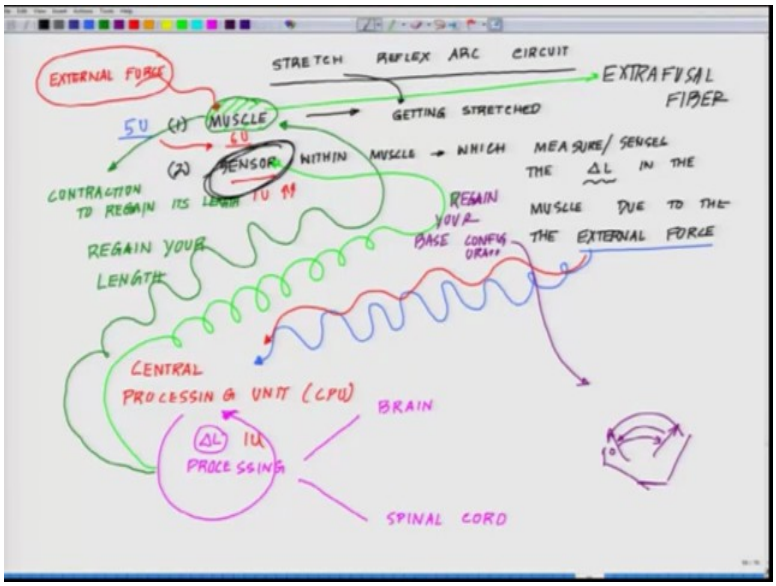

So, now we are entering into the domain which is at interface of nerve and muscle stretch reflex arc which is a reflex circuit which is one of the most primitive circuit stretch reflex arc circuits mind it.

I have not formally introduced you to the neurons yet. I am just giving you a feel of it that will help you to appreciate the problem much better than the formal way of you know just introducing neurons. So, here you have what are the players. First of all, there is a muscle which is getting stretched, then there is a sensor within muscle or this muscle itself can do this as both act as a sensor. Also the sensor within muscle which measure or senses the change in length as delta l in the muscle due to, by the way I forgot to mention something. There is an external force which is leading to the stretch external force, right. There is an external force.

So, measured or senses and the change in length in the muscle due to the external force now next it relays the signal through a pathway after sensing the change in length say for example, initial length of the muscle before the force generation is 5 and say 5 unit, this is the length. Then, post force generation, it becomes a 6 unit. There is an increase in 1 unit. So, this sensor will sense 1 unit increase and this 1 unit increase signal will be sent to the central processing unit. We will later introduce it formally central processing unit or the CPU which we are denoting as the nervous system, then relays process this

information. So, it has a processor, RAM processor which is you know a processor which is processing it.

This processing could happen at two level; theoretically and practically which I have. It could either happen at the brain level or it could happen at the spinal cord level. Now, this information is processed and it calibrates that there is a change in delta l change in length which is in this case is say 1 unit change. Then, what this will do? This measures this change and after that it sends process signals to the muscle back to tell it regain your length and then, muscle execute its contraction to regain its length.

Simultaneously this central processing unit sends another signal which I am putting on the lighter green colour to this sensor because there is a change in the length of the sensor to regain or you can pick up another colour, so that you can regain your base configuration. It is like configuration. It is like you are using a galvanometer or voltmeter. So, you see there is shift because of now this is 0, there is a shift. You have to come back. The galvanometer has to come back or a voltmeter or a ammeter has to come back to its original position before it can make the second set of reading. Otherwise from there it will go further up right. You cannot afford that. So, you need it to come back to its ground state, right. So, for such a simple circuit you think the amount of complexity it undergoes. So, this is one of the very fundamental circuit within our body which brings us a formal entry or a gateway into the world of amazing world of neuroscience, but then in the previous slide I told you remember these two words intrafusal fibre and extrafusal fibre. Why I told you this?

Now, let us complete the story. Now, these two words, this original muscle what you see all the muscles in our body, these are extrafusal fibres.

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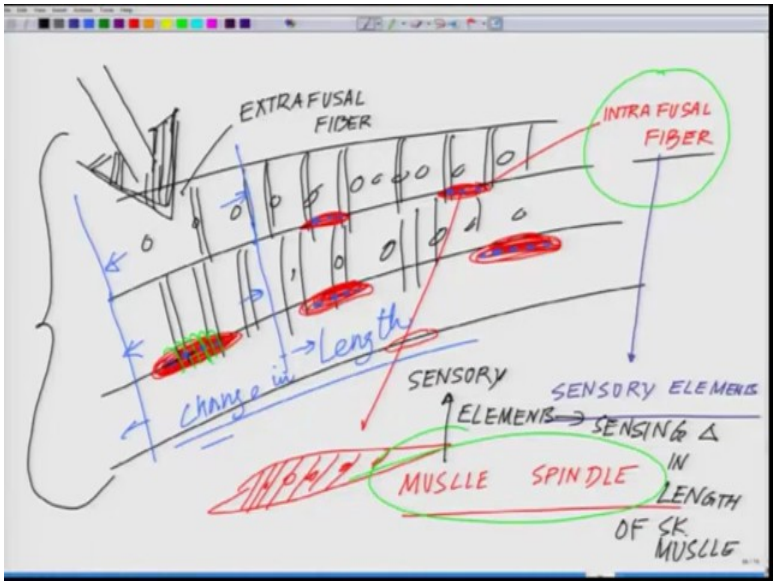

Now, within the extrafusal fibres, if you see a extrafusal fibres, if you see the muscles like this, skeletal muscle with striations and you know like this the multinucleated bodies and striations like this in between you will see some very small stuff like this, a spindle shaped structures like this and these spindle shaped structures which I am drawing in red now could be very prominently seen in the snakes. As a matter of fact many of these have been discovered in the snakes. The snakes body is, snake move like this, right. They have lot of these sensors and these red ones what you see are called intrafusal fibre and this is your extrafusal fibre and these intrafusal fibres are nothing, but this sensory element. These intrafusal fibres are sensory elements. These are also called; there is another word which are used for these intrafusal fibre. These are also called because of their shape; they have a shape like this. These are all multinucleated. These are also called muscle spindle, ok.

So, now I introduce you to another dimension of muscle, but now we are also introducing something more. Now, we have to redraw the circuit. Now, I have shown you the anatomy of it. These are the extrafusal fibres. So, our body is skeletal. Muscle of our body are mostly a large of it, it is nothing, but extrafusal fibre, but there is a small portion of it, very small very few percentage of it which is intrafusal fibre: now, having said this now think of from the developmental biology perspective.

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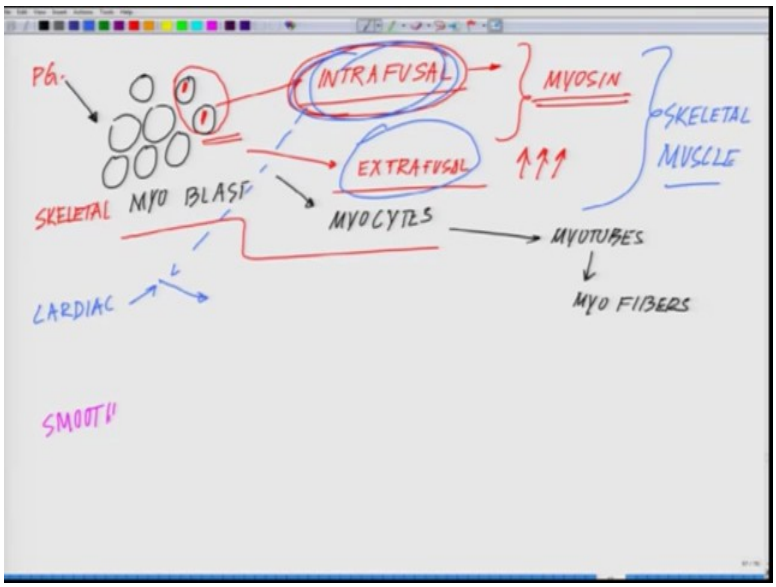

I told you that here you have a population which is this time to become muscle. So, myogenic lineage myoblast, right from myoblast I told you some form or junk from myosites form the myosites, they form myotubes and then of course followed by myofibres and if you see the hierarchy, you must have if you remember if I go back to that hierarchy.

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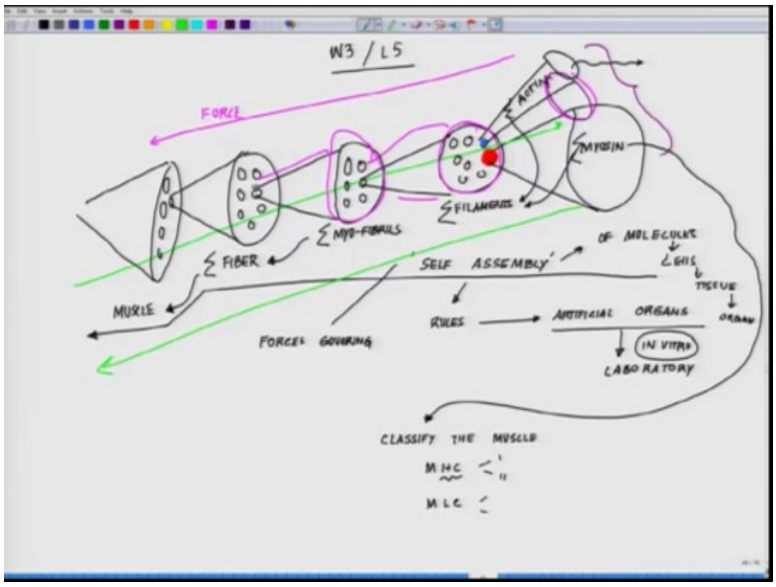

So, there you see the hierarchy. How this works? Now, in this whole process when this whole hierarchy is being happening, it is moving like this, different level. This is going in the smaller size and if you revise back, you are increasing the size in this process. Now, coming back where I was in this whole process, some of these myocytes or maybe myoblast, it is never clear. Now, we are just talking about these myoblast are for skeletal muscle. So, though at this stage it is decided which will go for the skeletal route, which will go for the cardiac route, and which will go for you know the smooth muscle route. Now, at this point we only talk about this skeletal muscle.

If we talk about the skeletal muscle at this stage, there is a second level either at the myoblast stage or the myocyte or even further back at the progenitor level PG level, there is a small population of it which becomes intrafusal and to the best of my knowledge as of now, no one has been successful to figure out at which one will become intrafusal and what all that small population and from here if you take this how we can convert them into intrafusal.

There are few works I will give you some. I will give you some reference material and you can go through if you are interested at what becomes intrafusal, but these intrafusal as compared to other one which the large number issuing up, where are issuing the large number the extrafusal, the fundamental differences again in the myosin. The myosin subtypes of these intrafusal fibres are very similar to the myosin of cardiac muscle. We will come later into that what kind of myosin fibres which are present there, but the myosin chains are entirely different of the intrafusal fibre as compared to extrafusal fibre within the skeletal muscle.

Now, having introduced this in concept of intrafusal and extrafusal, what we will do next is, we will develop the circuit from here I told u that. So, this is where the spindles are sitting and spindles are exactly you can consider them as spindle shaped myotubes. These are the spindles which are sitting there and these spindles also have multinucleated bodies like this just like the extrafusal fibres, but they are distinct and they are some very unique stains by which you can label them.

Now, whenever there is an impact falling in this muscle, now let us start with it.

Whenever there is an impact whose arrow is showing the impact, when the impact is falling what is happening here the length of this is changing, this whole part length is changing. So, this is it. Change in length, this change in length is sense by this element which is present there and interestingly if you look at them in a cross section of a muscle in a thin slice of a muscle, you will see two distinct innervation of a thread like innervation on their surface.

Those two different threads like innervation is something which will come now. So, let us again re hash. So, here you are having the intrafusal fibre in the form of muscle spindle. That is the terminology which is used, which are the sensory element sensing change in length of skeletal muscle. So, now our next job will be to dissect out the innervation of the neurons which are the threads like.

So, today what we will do, we will close in here and the next class slowly we will move on to the innervations and we will formally introduce what is a neuron, how it transmits its signal and how this complex circuit functions and what made us what we are.

Thank you.