Neuroscience of Human Movement
Department of Multidisciplinary
Indian Institute of Technology, Madras

Lecture – 22
Receptors – Part 1

So, welcome to this class on Neuroscience of Human Movement. This is the class on Receptors. So, most specifically, this is a class on Muscle Spindles, a special type of sensors that are responsible for detecting changes in muscle length and changes in muscle velocity; very very special this their functions critical for the functioning of the motor system, how do they work. So, this is the class on Muscle Spindles.

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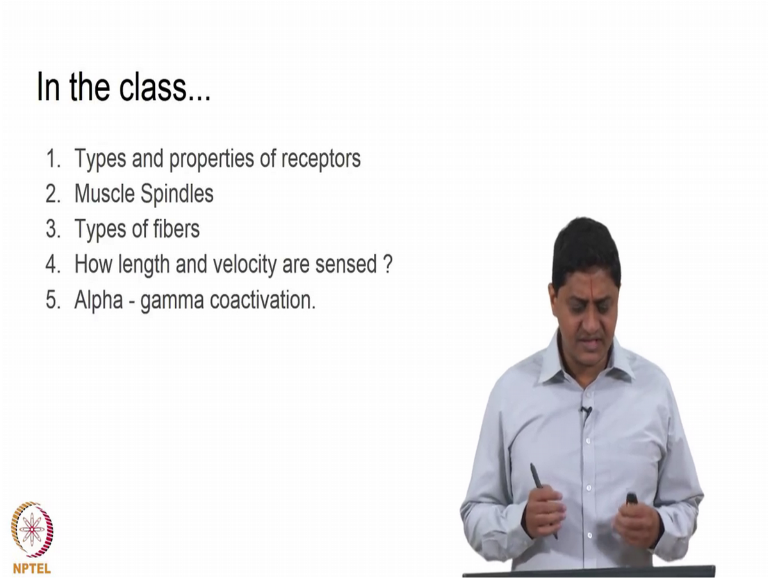

So, in this class we will however, we will start up with the types of receptors and we will focus on muscle spindles are types of spindles, how are length and velocity is sensed and the an important principle called alpha - gamma co activation.

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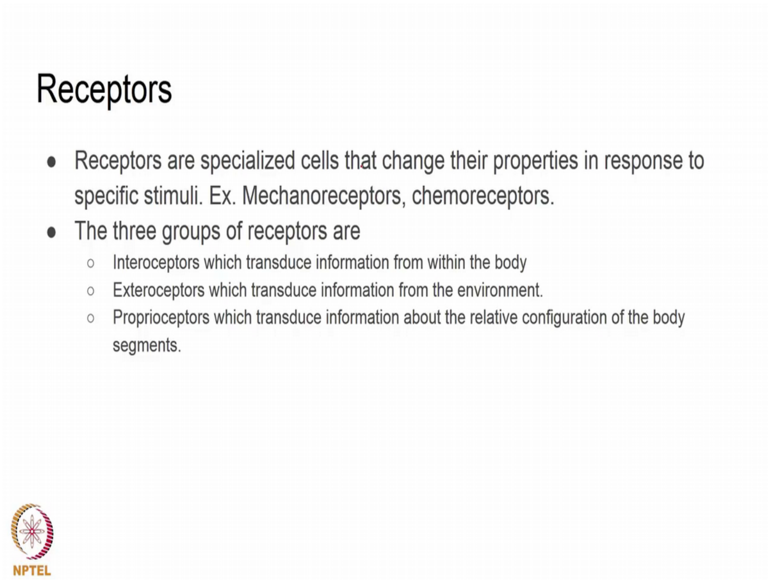

So, what are receptors? Receptors are special neurons whose properties, whose firing rate or some properties are changed in response to specific stimuli. So, this stimuli may be you know temperature, so that maybe with may more receptors and maybe some chemicals, chemo receptors and they may be you know these receptors may sense some mechanical change like pressure. So, pressure that is applied to say a part of the body or pay in note receptors or those that sends mechanical stimuli, you know mechanoreceptors those, those that sense changes in light, changes in you know the optical properties.

So, basically receptors are in some sense sensors of stimuli of different moralities. So, in general we can classify this is a receptors for philosophically we could classify these receptors into three major types; those receptors, those sensors that you know give us information that about what is happening within the body, inside the body, what is happening within the body they are called as Interoceptors; that give me information about what is happening outside the body from the environment, things that are happening around me, I am able to see what is going on and I am able to hear that sound, it is some sound is coming I am able to hear that.

So, those are happening in the environment but it I am able to sense it, I am getting information about what is happening in the environment right. So, those sensors that give me information, those receptors that give me information about what is going on around me are from outside my body I called us Exteroceptors. Then, there is the special class; the special group of receptors that give me information about where my specific parts of the body are, in particular where my limbs are, where my where is my hand and where is my leg, where is my arm and to how much angle I have moved my you know arm for example, information about the relative configuration of the body in some sense, I am have, I am able to find a difference between that angle that I am keeping and that angle that I am keeping; I know, we know.

For example, I could do this very simple exercise, I am going to close my eyes, I am going to do the following you know. I am going to first move my right hand to one angle and then I am going to move my left hand to the same angle. You will notice that you know they are approximately correct even though I am not seeing my hands. How do I know to what extent my right hand has moved? Anybody could do this exercise, you could also do this exercise. You will find that you are also able to repeat this; what is what is better I am also able to do that for example, right. I am able to touch two index fingers with relative accuracy, well not exactly touching but I am not missing it. I am able to do that with relatively you know sufficient accuracy. How am I able to do that? How do I know where my right hand arm is traveling?

So, for this to happen, I should know where this the trajectory after this fingertip, the right fingertip and the left fingertip should somehow adjust it is trajectory in the 3 D space in such a way that these two touch relatively complicated thing; for example, in computer science in engineering in robotics something to achieve something like that would be you know substantial achievement, would be great is my relatively complicated, yet we know and we do this all the time. We take this sense for granted. We are able to do this with relative is. That is possible with the help of this information is coming from a special type of receptors called Proprioceptors.

So, this class the entire today’s class and probably the next class and also dedicated completely to the discussion of Proprioceptors ok.

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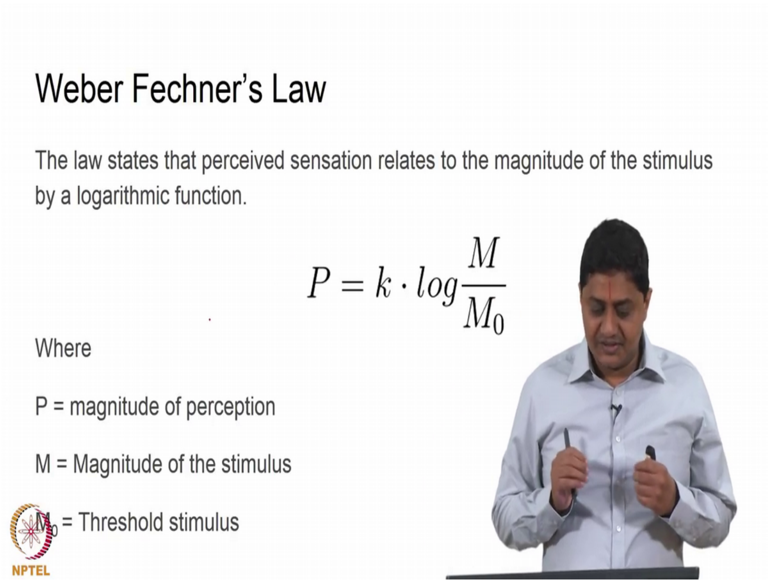

So, one thing that goes with whenever we are talking about you know perception, you need to talk about how is perception even achieved, what are the are there some laws or rules that govern perception. It turns out that there are some laws and rules that govern perception. Actually, this is the famous labor hyphen Fechner's law, actually this refers to two separate laws; first is the Weber's law that talks about the just noticeable difference, not discussed on this slide is the just noticeable difference is the smallest difference that a person can sense, right.

So, that depends on what the initial value was right, what the initial sense was. Suppose, I am holding this object that says it is mass is 500 grams and I am adding 100 more grams, now you are asking me to find how much how much weight has been added; I am saying some number. Suppose, I had only 100 grams and I am adding 100 more grams, what would you perceive as greater weight. So, I had 100 grams and if 100 more grams is added, the chance is that I am going to perceive the case where the initial mass was 100 as the heavier load.

So, there is in some sense, the load detection load depends on the initial load. So, if I had 100 grams or and I add 100 more grams, I am going to perceive something; I am having 500 grams and I am adding 100 more grams, note in both cases I am adding the absolute a addition to load is only 100 grams but the detection will vary depending on what the initial mass is not.

So, that goes to the Weber's law where that describes the just noticeable difference. Actually, the just noticeable difference is the smallest such change that can be [det/ detected] detected and the smallest such change that can be detected depends on what the initial value is. So, that is that, then we go to Fechner's law where the relationship stimulus and the threshold of the stimulus and the perception that is detected is logarithmic; in other words if the stimuli changes in a geometric progression, then my perception changes in an arithmetic progression.

So, the difference is stimulus gets multiplied; every time the stimulus gets multiple. So, just describing what is geometry progression you all know what is geometric progression in arithmetic progression the stimulus gets multiplied whereas, my perception gets added. So, that is what in an easy way of you know remembering what this logarithmic relationship means. So, the perception changes as a logarithmic function of the stimulus I with respect to the threshold stimulus.

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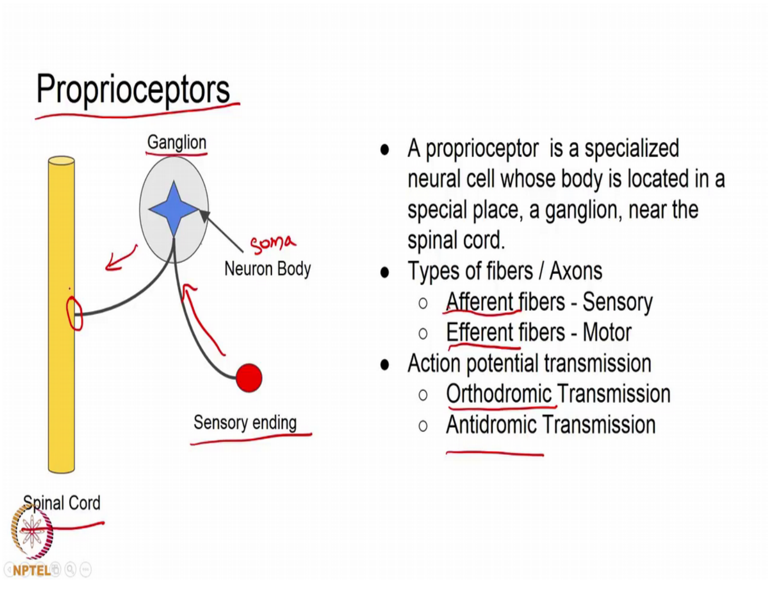

So, this law has come to be known as a Weber's Fechner's law of perception. Today's class, we wanted to focus on proprioceptors I said proprioceptors are those neurons, those cells that are specialized for body location body relative position since right. How is that since, there are different types of proprioceptors. In today's class, will focus on one type, we are going to call this as muscle spindles, we are going to focus on you know on muscle spindles in today's class.

They have a special property these neurons near the spinal cord in a in a Ganglion and they have a special property in that, there they have they branches of axons. So, this is one axon that is shown here this is the other branch of the axon and there are two types of conduction in general in neurons there are two types of conduction. In general, conduction from in a neuron happens from the cell body, this is the soma, this is the soma or the cell body. If the conduction happens from the soma to through the axon in that direction for example, that is called as Orthodromic conduction; if the conduction happens through the axon to the cell body, from the axon to the cell body in that direction; for example, that is called as Antidromic conduction.

In general, neurons have one of these steps; either neurons conduct Orthodromically or Antidromically, but proprioceptive neurons are special in that these neurons conduct both Antidromically and Orthodromically. It is two axons, it is two branches conduct in two different directions; one of them brings information from somewhere to the cell body where it is processed, integrated to some extent and then it another one carries that processed integrated information to somewhere else, the other action [carri/carries] carries it from there.

So that means, there is both Orthodromic and Antidromic conduction that happens in these special neurons, a case of motor neurons right where information from these neurons can cause a movement, cause a contraction of the muscle. These neurons that cause or these fibers that cause a movement or a motor activity are called as Efferent neuron fibers and those that sense information that is happening on are called Afferent ok; these two, the pronunciation of both are somewhat confusing; one is Afferent, another one is Efferent ok. Efferent is the motor one and these proprioceptors are Afferent neurons are Afferent fibers.

So, the Proprioceptive neurons are special in that you know they have both Orthodromic and Antidomic conduction and they get the information from somewhere, from a sensory ending from a point where I want to have the sensing and they send the information back to the central nervous system to the spinal cord. Actually, what happens here at the spinal cord and where does the information go will reserve for future classes. We, our interceding studying how muscle spindling is alone function, that alone is part of today's class.

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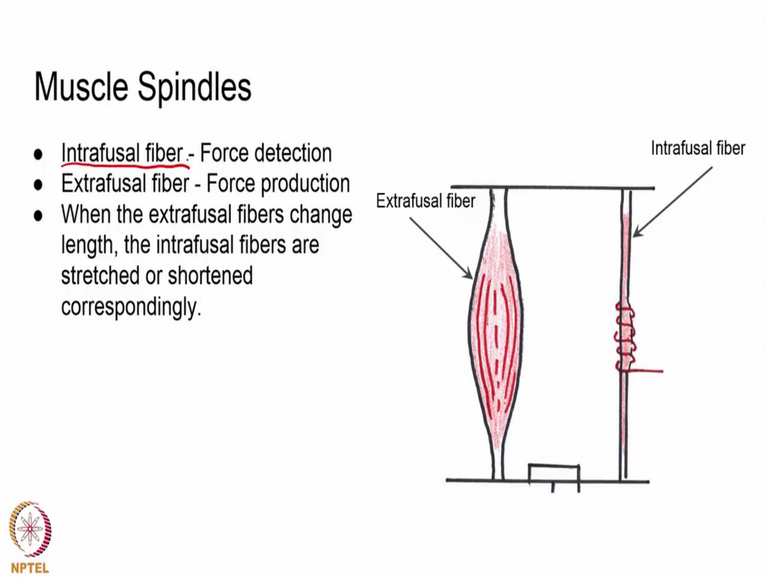

So, Muscle Spindles consist of two types of fibers, lots of terminology. There are two types of fibers; first is Intrafusal fibers. These fibers are those that are located on the central part of the muscles. They do not participate significantly in the force production activity of the muscles. So, a muscle is composed of two types of fibers; one is Extrafusal fibers. These are the fibers that produce force as we saw earlier, the sarcomere sliding filament theory, excitation contraction coupling and cause of force that is being produced.

So, Extrafusal fibers produce force, Intrafusal fibers and also muscle fibers but they do not contribute significantly to the change in the total muscle force. So, these are more useful for detection or force detection or length detection or something else, detection of some physical change. When the Extrafusal fibers change in change length, the Intrafusal fibers will also change length; why because it turns out that the Intrafusal fibers are located in parallel to the Extrafusal fibers.

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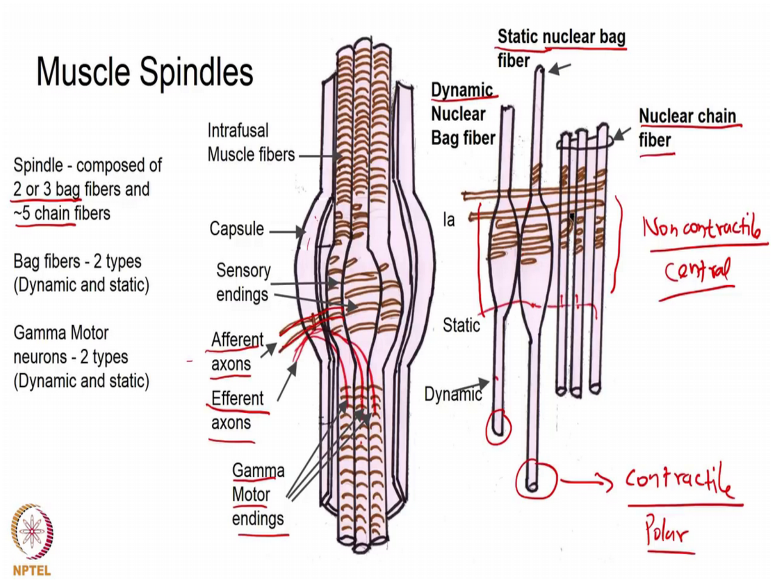

There and again there are different types of these fibers. We will just first we classify this as nuclear bag fibers and nuclear chain fibers. Those that are you know those that have a bulging in the middle of that type right are called Bag fibers.

And those that look like several chains are called as Chain fibers and there is a subdivision of these. These nuclear Bag fibers are divided into two types; the Static nuclear bag fibers and the Dynamic nuclear bag fibers and it turns out that all this together I will present in a muscle spindle. Usually, a spindle is composed of two or three bag fibers and a different say number of chain fibers, usually around five chain fibers are present.

So, two or three bag fibers and five chain fibers together constitute one muscle spindle and what did they do, what is their function? It turns out that these Intrafusal fiber I said stretch when the muscle is stretched right. So, when the muscle length changes, when will the muscle length change when the muscle is stretched, when will the muscle get stretched? There are two, there are only two possibilities for the muscle to stretch; first an external force is stretching the muscle, for a this is the kind of exercises you would do when you go for stretching exercises. I will do mostly the type of exercises that we do in Pilates or in yoga involves some amount of stretching, most of those exercises are stretching exercises, right.

the in many of these cases, we what we do is we stretch against non moving things; is it not, against the environment. So, in such case as an external force is involved. This is one case in which you could in which the muscles are stretch; the other case is the case where the antagonist is contracting. So, the usual example that we give is when I am doing this, when I am flexing the elbow or when I am reducing the angle between my forearm and the upper arm that is flexing of the elbow joint, when I am doing that, the biceps muscle is contracting, but it is antagonist is the triceps that is getting stretched. So, why is the triceps getting stretched; because the biceps is contracting.

So, and our interest is in a detecting this stretch, we need to get a relatively accurate information about what the state of the muscle is and this by the way this information needs to be obtained for practically all the skeletal muscles. So, lots of these spindles are present throughout the body ever in all the muscles concerned. So, our interest is in understanding how this is detected,how this stretch is detected.

So, what actually happens is that, so there are these types of fibers that are located and they are all located in a capsule and then what also is present. So, these are the muscle fibers and their properties, what are the properties? They are basically composed of these fibers, but not just that, we said that there is proprioceptive. So, that is this part, that is this part but then, information from this must somehow go to the proprioceptor neuron, is it not?

So that means, there is innervation. There is innervation of or the neural innervation of these fibers. Actually, the it turns out that there central regions of these fibers are non contractile. So, they do not contract or they do not contract by much. The central regions of these Intrafusal fibers are non contractile whereas the polar regions, the end regions are contracted.

So, the central regions are innervated by the afferent axons coming in. So, the afferent axons come in and innervate the central non contractile regions of these fibers. So, when and these afferent axons have the property that when the fiber is getting stretched, the axon also gets stretched and when the axon gets stretched, it stretch sensitive ion channels present on this axon cause a lot of influx of sodium causing an action potential in that axon and this action potential travels back to the soma, ok.

So, basically straight sensitive ion channels present on the afferent axons are getting activated when the fiber is getting stretched. So, the fiber gets stretched on top of the fiber are these axons, the axons get stretched or the endings of these axons get stretch and the stretch sensitive ion channels are opened sending in a lot of sodium and causing an action potential in this axons which is then detected by the proprioceptor neuron,.

These axons are loc are innervating the non contractile central regions. The non contractile central regions are innervated by the afferent axons, is it not? So, the non contractile central regions when they are getting stretched, the innervated axons produce an action potential and. But then, what else is also present are some efferent actions, some other things are also there; these efferent axons what they do they innervate not the non contractile regions but the polar regions, the endpoints of these are innervated by afferent or efferent axons and these neurons are usually called as gamma motor endings.

So, this is different from the other motor neurons, Extrafusal fibers right are the force producing fibers are innervated by motor neurons basically the neuromuscular junction case that we saw, is it not. So, they produce force and these motor neurons that innervate the Extrafusal fibers are called alpha motor neurons and those that innervate the Intrafusal fibers, the contractile polar regions of the Intrafusal fibers are called as Gamma motor neurons. They perform some special function. It is not clear what that special function is we will see in future slides.

So, this is the architecture of the muscle spindle. They are composed of different types of fibers; basically bag fibers and chain fibers and bag fibers are divided further into two types; dynamic and static. And they are composed of a central, non contractile region and a polar contractile region and they are innervated in the center by afferent axons and in the end by the efferent axons which is also called as a gamma motor system, ok.

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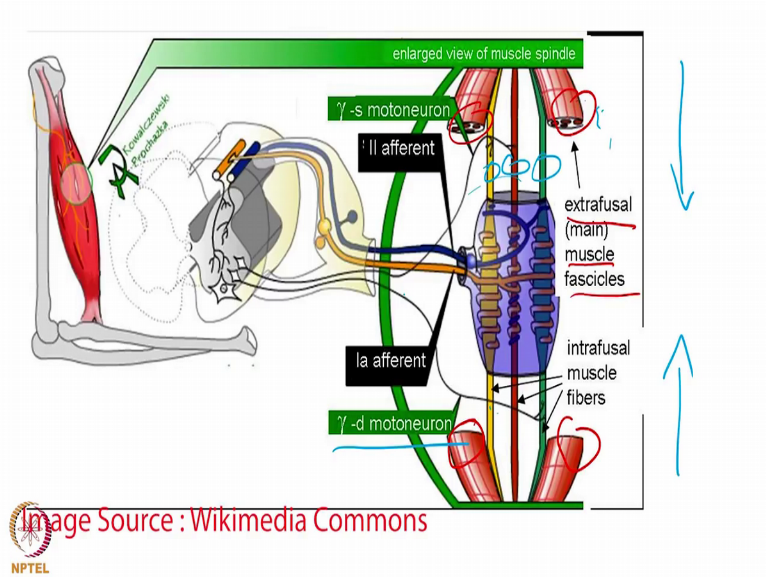

So, an example that is given here is. So, these are these that are shown here, these are the Extrafusal of a muscle fibers and their fascicles. So, this is these those that I have circled with red are all the Extrafusel fibers and those that I am now circling with blue here these are the Intrafusal fibers. So, what happens is that whenever the extra the muscle is getting stretched, what happens the Extrafusal fiber gets stretched. So, or in other words, this moves in that direction moves in that direction.

And so, the capsule becomes a stretched, this capsule becomes stretched and the afferent axons attached to these capsules also get stretched and that stretch is getting detected.

But a question is what would happen muscle is contracting? Is it that this is going to when I said that these channels are stretch sensitive, there is no such thing as slack sensitive right because I can have I am having this thread when I am stretching this thread or I am having this rubber band say for example, when I am stretching this rubber band, the more the stretches if there is a stretch sensitive sensor here, the more the stretches more is, the signal that I am going to get. But if I am slacking it, it is spa, it is not possible for me to detect the amount of slack in some sense right; is it that these muscle spindles can detect only stretch from a 0 resting length, but not contraction, but not slack?

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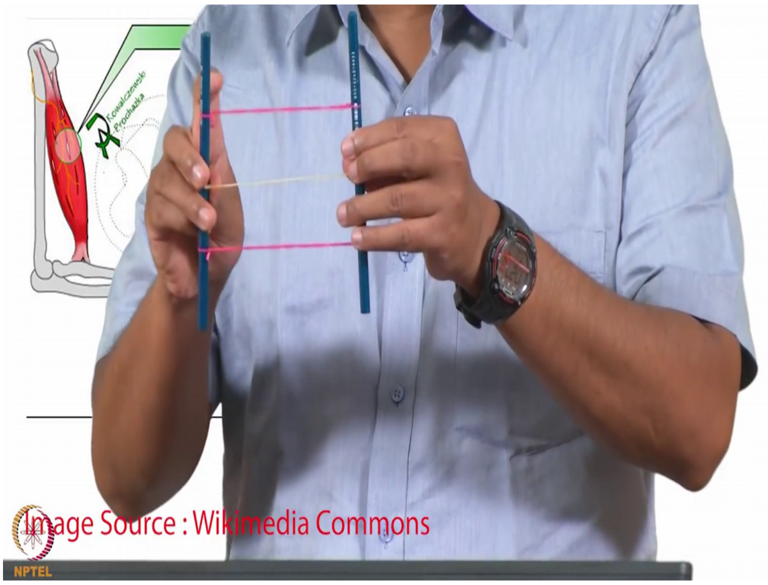

Here is an illustration explaining the situation. Here, there are three rubber bands, it there are two red rubber bands. These are the two and there is a green rubber band in between right. Let us assume that the red rubber bands represent the Extrafusal fibers or the force producing fibers and the green rubber band represents the Intrafusal fibers right; the ones that are useful in measuring the length. The amount of stretch that the Extrafusal fiber stake can also be measured by their amount of stretch of the Intrafusal fibers, this is what we have seen.

Now, how do you measure slack? Suppose the extrafusal fibers are contracting like that right, suppose they are contracting, how do we measure contraction our slack itself, that is the question. Now, in this case what would happen is when the muscle is contracting like that or when the extrafusal fibers are slack, we must somehow ensure that the intrafusal fibers which is the green band here remains out and this is achieved by pulling at the end like this right.

So, when I am pulling the intrafusal fibers at both ends are at the polar regions which is where the gamma motor neurons innervate. So, the gamma motor neurons innervate at the two ends or at the polar regions and they cause a contraction at the ends thus keeping the central sensitive region taut at all tension. So, regardless of whether the extrafusal fiber is slack or taut, the intrafusal fibers is always maintained to be taut. What happens is that as the muscle is getting contracted, the extrafusal fibers move closer or you know become shorter in that sense but at that time, the polar regions of the intrafusal fibers are innervated by the gamma motor neurons. These gamma motor neurons are also getting activation in such a way that the polar regions that are contractile are getting pulled.

So, these guys, the x and the outside the extrafusal fibers contract but the those that are in the center expand, get stretched in a in a way by sending information by contracting the polar regions this polar region and that polar region, effectively I am stretching by sending that information, I am keeping the central sensitive region taut are sensitive to stretch.

So, if I know then since I am the one, since the central some from somewhere in the central system you are sending this command to the gamma motor neuron to contract the polar regions, this is not. So, I know how much command I gave to keep this polar regions contracted or to keep this system taut. So, in some sense that is a gain multiplier, I know how much information I gave.

Now, whatever else in whatever else is the information received from the afferents from the from these afferents must be multiplied or must be you know computed along with the information that I gave to the gamma system. A combination of these two together will give me the exact state of the muscles.

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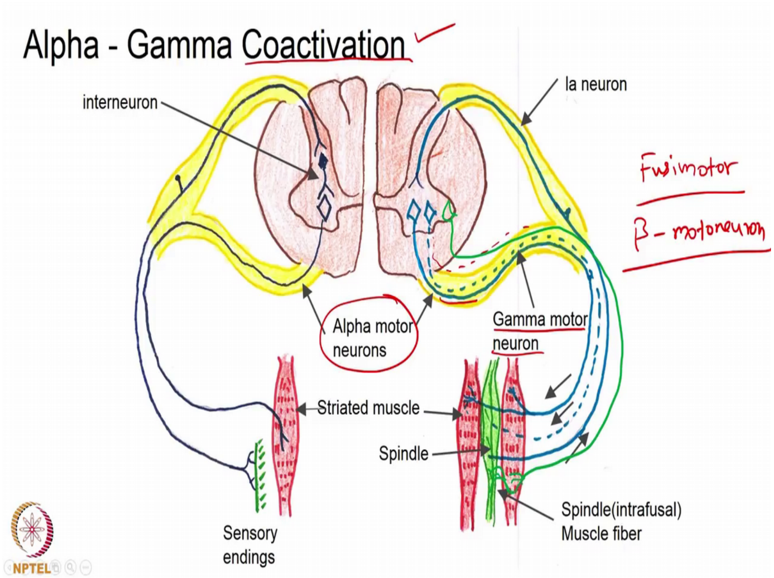

So, what actually happens is that whenever the extrafusal fibers are activated, extrafusal fibers are activated how? Extrafusal fibers are activated by alpha motor neurons by these neurons that are shown with a solid line here right, by these alpha motor neurons, those that are shown with a solid line here. Whenever they are activated, the muscle will contract but at the same time, I went the muscle contracts I want to have accurate information of their lengths, there is a simultaneous activation of a different motor neuron, these are the gamma motor neuron. What are the what is the gamma motor neuron doing? It is going to activate the polar regions of the Intrafusal fibers.

Those that line is shown with the dashed line here is it not these dashed lines. So, the intrafusal fibers are kept simultaneous active. So, what is the difference between the alpha motor neuron and the gamma motor neuron? Alpha motor neuron are large diameter myelinated axons whereas gamma motor neurons are small diameter myelinated axons. So, we saw early on or in one of the earliest classes, what we saw was that you know myelination increases conduction velocity. We want to how the greatest conduction velocity for sending information to the move to the muscles to perform movements.

So, alpha motor neurons have large diameters and they are all myelinated and gamma motor neurons in comparison have relatively smaller diameters, but they are also myelinated. So, they are going to contact with the slightly lower [velo/very] very slightly lower velocity because there the information is coming from the spinal cord through the muscle of interest. Is it not? So, they are small diameter myelinated axons and they both and they are both simultaneously activated by a process called alpha gamma co activation. Whenever alpha motor neuron of a muscle is activated, there is simultaneous activation of it is gamma motor neurons so that whenever this muscle is, I know what alpha motor neuronal activation will do, what alpha motor neuronal activation will do? It will contract the muscle is it not it will cause the extrafusal fibers to contract by excitation contraction coupling. At the same time, I do not want to lose information about the length of this muscle. So, I want to stretch the intrafusal fibers. I do that by sending information to the contractile polar regions of the intrafusal fibers that I am doing with the help of a different system with the help of gamma motor neurons and they are simultaneously activated. That is why this process is called as alpha gamma core activation.

A special process not discussed so far, a special case not discussed so far is the case of Fusing Motor System, at the scale to fusing motor system. This is the case when send distal muscles of the limbs. I want to have very good sense of what is going on; in those cases, what it does is there is a special system not discuss as part of this. This system is called as the beta motor neuron system different relatively less numerous, relatively rare, relatively rare when compared with alpha and gamma, this beta motor neuronal system. What this does is, so that I am going to draw with a different color here. Suppose this where are a distal muscle of a limb say the hand for example, in that case you have a special neuron.

That neuron is going to come like that and you know go like that. What it is going to do is it is going to innervate the Extrafusal fibers yeah and also the Intrafusal fibers. This is a special case. Extrafusal fibers are usually act you know innervated by alpha motor neurons, intrafusal fibers are usually innervated by gamma motor neurons. A special case is the case of a fusion motor system where only in some cases, relatively rare cases, a neuron innervates both the extrafusal fibers and the interfacial fibers of the same muscle. What would this do?

So, as soon as the contraction, command for contraction is given to the Extrafusal fibers, simultaneous command for contraction of the contractile polar regions are stretching of the interfusal fibers is given. So, this has collaterals to both extrafusal fibers and interfacial fibers, a very special case but the more common case is the case of the alpha gamma co activation.

So, basically beta fusimotor system are beta mode neuronal system is a special case of the alpha gamma co activation system. I could activate what is the difference in the difference is that alpha motor neuron is a large diameter neuron, gamma motor neuron is a small diameter neuron, beta motor neuron is a medium diameter neuron. This is one difference, the other difference is alpha gamma core activation although the command is given simultaneously these are given to two different neurons.

Here, but in the beta case, command is given to a single neuron. It is dividing it is command to both the Extrafusel system and the Interfusel system. So that means, in the reliability of this system, the beta system is going to be more than the reliability of the alpha gamma system because there are two you know, two elements that are involved, two independent elements that are involved in alpha gamma system. There are two neurons; in this case there is only a single neuron; one you run inner wedge both the Extrafusel and Interfusel.

So that means, there is more reliability why would this be needed because we use the distal part of the limb to interact with the environment. All the all the interactions that we do with [envi/environment] environment are with this, is it not? Anything I do, I am I am writing with the pen, I am clicking this clicker, drinking water or whatever I am doing, I am doing with the distal part. So, the manipulation needs to be more controlled or for some reason it is not clear why evolution we would do this but this happens.

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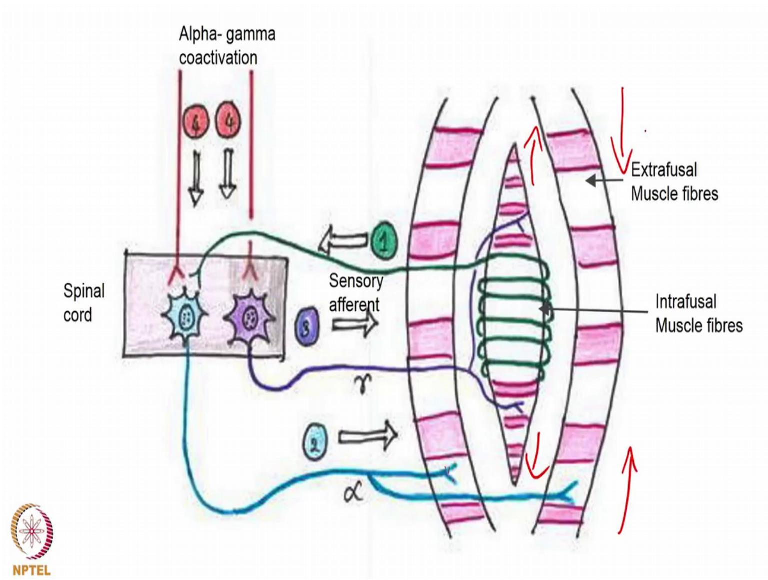

And we somehow this happens. So, as soon as the alpha system causes you know contraction, this middle portion gets stretched.

So, this is the extrafusal fibers, they are getting contracted right. They come closer to each other reducing this, reducing this length whereas the intrafusel fibers go farther away from each other increasing their length thus increasing their sensitivity. If I know what the sensitivity what the command that was given to the gamma motor neuron and if I also know I also know, what the input from the sensory afferent is. This is coming to me through the proprioceptive system. This [infimum/information] information from the gamma motor neuron is coming to me from the motor system. A combination of these two must give me a good sense of what the actual state of the muscle is. note, the motor neurons and the afferent neurons are located in two different parts of the spinal cord, they said earlier early on that the motor neurons are from the ventral part of the [final/spinal] spinal cord whereas the afferent system is usually located closer to the dorsal portion of the spinal cord.

So, ventral means, suppose I were standing on four legs, suppose I was standing on four legs, that part of the body that faces the ground is the ventral portion are this part this is the ventral portion; that part of the body that faces the sky or the roof is the dorsal portion. So, when I am on this that portion if the dorsal portion if this portion is the ventral portion.

So, the ventral portion can sense the, from the ventral spinal cord you get the motor neurons and from the dorsal spinal cord, you the innervation comes for the afferent are the are the sensory neurons ok. So, they are not they are not coming from the same neuronal pool, they are coming from two different pools of the spinal cord; yet, something else can happen that is the part of reflexes which we will discuss in future classes.

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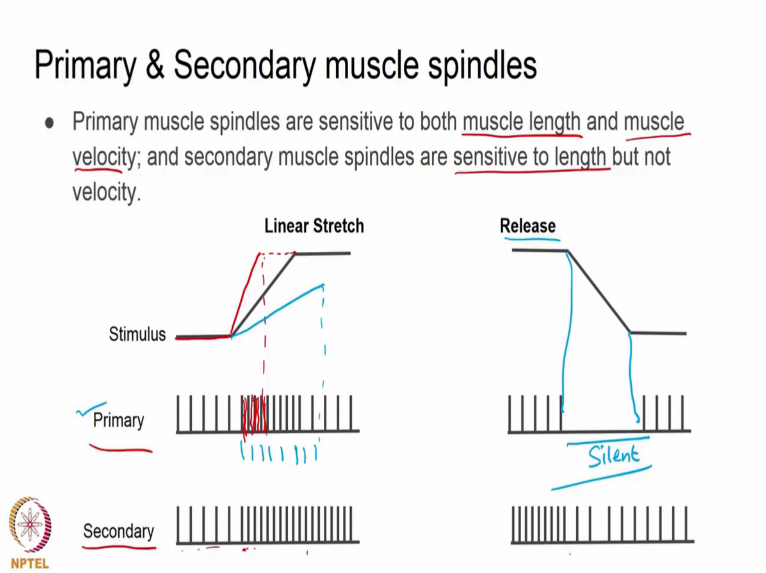

So, how do they function and important how do they still stretch how do they since stretch that is the question, how do they function? There are two types of these spindles; the primary spindles and the secondary spindles. The primary spindles are sensitive to both muscle length and velocity of shortening. They are composed of the dynamic fiber and bag fiber or chain fiber. So, they can detect both velocity and length by the use of the dynamic fiber.

So, the secondary spindle endings are sensitive to length but not velocity. These are composed mainly of the static bag fibers and the chain fibers. The chain fibers are static anyway. So, suppose there is that length and then length is, that length is very linearly for some time and then a new length is arrived. Suppose that is happening right; what will the secondary ending do is that as the length changes the frequency of firing of the secondary ending will increase at the new length. This is the new length. At the new length, that frequency will be continued to maintain a for as long as this length is going to be maintained for that long, this frequency of firing is going to be maintained. In other words, the secondary ending is a pure is a pure length sensor.

Whether the primary ending is slightly different more complicated than that, what it does is depending on the, so as I am increasing this length the firing increases in the primary ending, then I am maintaining a new length, then the firing decreases. So, here this is a code of this is a frequency code of the time rate of change of this length are the velocity of this length. Well, to explain this better let us consider two cases.

let me consider a case, suppose I am stretching this a little faster, you know like that and I am reaching the same new length and I am maintaining. What would be the response of the primary ending. That is the question, what will happen is that there will be all these black lines and in between there will be more red lines as in there will be more lines why because I am stretching them faster and that will happen only until at this point, but not these two ok. So, there will be more lines between these two.

So, or another possibility is that I could stretch slower I could do that, then what will happen is that this will become a little farther away from each other. These lines could become a little farther away from each other. So, from this, what I can deduce from this what I can understand is that you know by looking at the frequency of firing of the primary spindle ending, I am able to say what was the velocity with which this stretch was happening. So, if the frequency of firing is high, so basically the velocity is encoded in the frequency of firing of this primary, so if the frequency of firing is high, then the velocity will be low, the frequency of firing is low; that means, that the velocity is low.

A question is what will then happen, if I am releasing like this to the, so in this case, I am releasing from a stretch what usually happens is that this release from stretch. The sensitivity the static sensitivity of the gamma system is increased whereas, the dynamic sensitivity is reduced. It turns out that as we have said that there are static fibers, we have said that there are static fibers and dynamic fibers. It turns out that the gamma motor neurons also come in dynamic and static.

So, there are two types of gamma motor neurons also. It turns out that I can selectively change the sensitivity of the dynamic system or the static system. If I am going to unload, what this does? If I am going to release from a stretch, what this does is that the static sensitivity of this system is increased to a great extent or the static gamma motor neurons are firing whereas the dynamic gamma motor neurons are not firing so much; their dynamic sensitivity is reduced thus what happens exactly during this release is that the primary motor ending becomes silent practically. There is no input during release from a stretch; however, what happens, then you are worried then how will I detect length, there are others to do that job for us.

There is still the secondary sensory ending. I said this is only the primary, that is still the secondary sensory ending which detects length alone as the during release and during stretching during both stretching or released from a stretch whereas the primary motor ending can detect velocity and length and become silent during the release from a stretch,.

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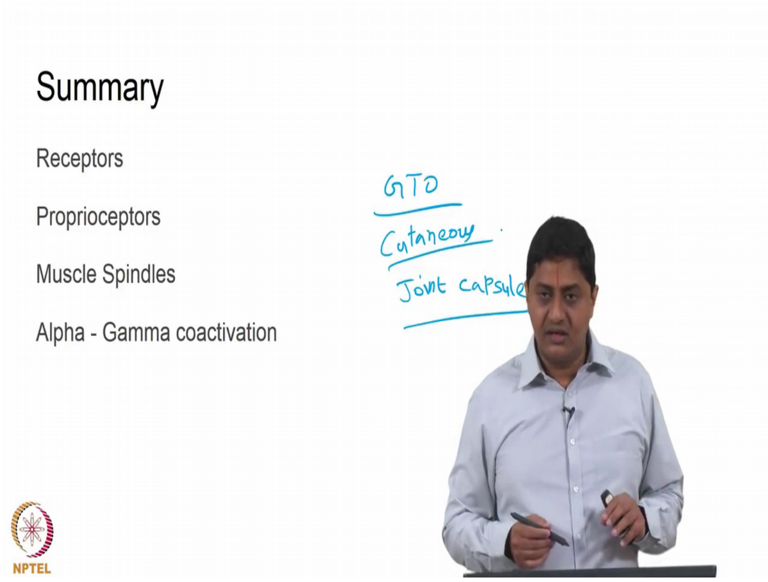

So, in summary what we have seen is we have seen receptors, we have discussed a little about Weber Fechner's law and the some proprioceptors these are neurons that are special that have two axons; one that receives information from the sensor sensory or ending. So, wherever I want to have the sensing at that part I have a sensor, from there I am receiving information that is one axon in which conduction is happening in Antidromic direction of conduction is happening towards the soma and then something integration is happening at the soma and then information is going to the spinal cord in Orthodromic. So, these are special neurons that can that have both Antidromic and Orthodromic conduction and that sends information of the relative body positions. And we saw muscle spindles and the types of fibers nuclear bag, nuclear chain, static and dynamic and the important principle of alpha gamma co activation that causes the polar regions of the interfacial fibers to contract simultaneously with the contraction of the Extrafusal fibers thus, maintaining the central region taut in such a way that you are always sensitive to stretch.

At no point does the muscle spindle become loose. There are other receptors that are not discussed in this class the other receptors are most importantly the Golgi, Tendon organs, not discussed. This will be discussed in future class and Cutaneous receptors and what are called as joint capsule receptors or the joint articular receptors; what do they do, what do this, what do these things to all these thing things together will discuss in the next class. And how do they help in motor control, we will discuss in future classes. So, with this we come to the end of this class.

Thank you very much.