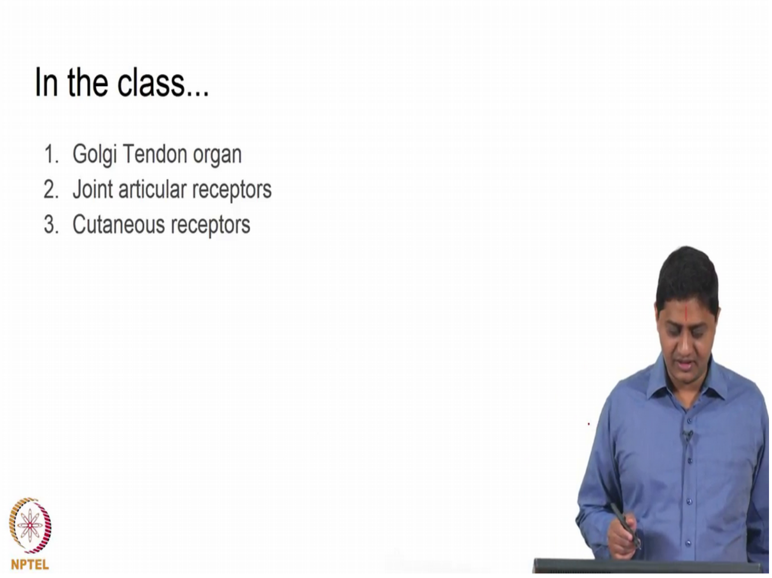
Neuroscience of Human Movement
Department of Multidisciplinary
Indian Institute of Technology, Madras

Lecture – 23
Receptors - Part 2

So, welcome to this class on Receptors Part 2.

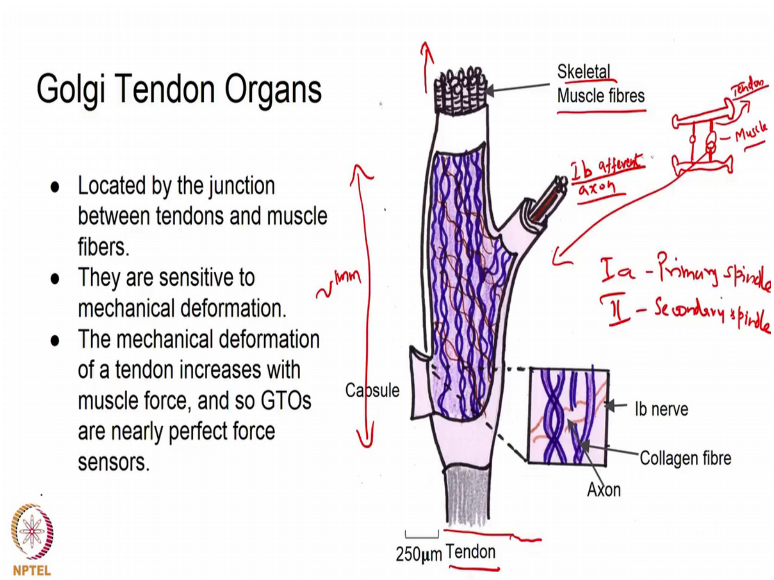
(Refer Slide Time: 00:20)



In this class we will be talking about Golgi Tendon organs, what are called as joint articular receptors, and some cutaneous receptors. In the previous class we saw the case of muscle spindles and how muscle spindles serve as a length and velocity sensors. So, in today's class we will see different sensor.

So, if a node in the case of muscle spindle we said that the sensor itself or the intrafusal fiber that is responsible for sensing the length is aligned in parallel with the force producing extrafusal fibers. This was the mechanism. But is there some other way in which I can know is there some way in which I can know the force produced by your muscle? Can I know the tension in the muscle? That is the question. The answer is yes, and the sensor that is responsible for the detection of tension is called as Golgi Tendon organ. So, how does this do that function?

(Refer Slide Time: 01:28)



Golgi Tendon organ is composed of capsule that is located between the muscle and the tendon are located near the junction of the muscle and the tendon to remind ourselves what the situation is. So, let us say I am going to draw 2 bones. So, that is a bone representationally. There is another bone here. And we said that movements are produced by relative movement of bones, is it not?

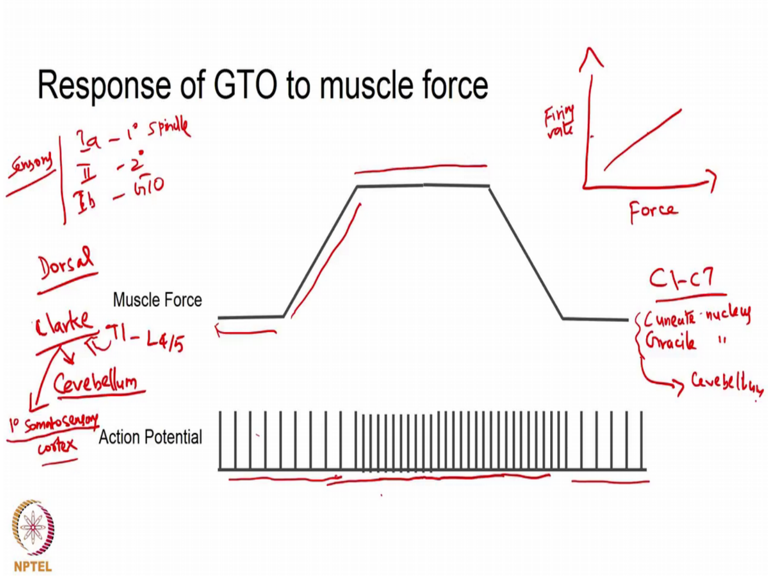
Let us say that is the muscle and so, this is called as a muscle or the muscle belly. This is composed of contacted material and is neurally innervated. And the muscle is attached to the bone via tendons this attachment. So, what are what are the tendons composed of? They are also composed of contacted material; mainly they are composed of collagen. This muscle when it contracts or when it is length reduces.That means, that that will happen when the neural activation makes that to contract like that for example. Then what will happen either the bones will move relative to each other or the tendon will elongate ok. This is the process. In a different class we will discuss the details of this.

So, the tendon is attaching to the muscle at that point. So, what you are seeing here is a zoomed out version of that. So, if we zoom out that, on the one hand you have the muscle fibers and the other side you have the tender ok. So, I am zooming out that part where the muscle is attaching to the tendon in between the attachment, you have a capsule that is composed of fibers, that is intertwined by a neuron axons of a neuron this neuron is; so, this axon is called as a 1 b afferent axon, we saw that the 1 a afferent axon is the primary spindle ending.

And 2 is the secondary spindle, is it not? When this is getting pulled; suppose, this tendon is attached to a bone here, this is getting pulled when that is getting pulled gets compressed because of the collagen fibers. So, the collagen fibers become uncrimped. The collagen fibers elongate and compress the neighboring 1 b axon; as the tension in the muscle increases the compression of the collagen fibers increases. Because the compression of the collagen fiber increases, the number of channels going to be affected by the compression of these collagen fibers and in this 1 b afferent axon is going to increase producing you know action potentials.

So, what does this mean? When will when will this fire; that means, whenever there is an increase in tension of this muscle, there will be an increase in the firing rate of this 1 b afferent axon of this neuron. So, because of this reason Golgi Tendon organs are nearly perfect force transducers nearly very good force sensors. And a question is how do we know this? It turns out that there have been experiments on animals.

(Refer Slide Time: 05:10)



Where they have studied the force versus a say firing rate or the response rate (Refer Time: 05:23), and for different in different Golgi Tendon organs are the force increases. So, there are that is not there. So, with different slopes, but in general what you will see is that you know as the force increases the firing rate increases.

So, if you take an ensemble of all these things, you are going to get something like that. So, this is a relatively accurate force transducer, and with some slope rate. So, if we if we know what the slope is and I am going to be able to estimate the force depending on the firing rate if I know the approximate slope. So, I am going to be able to do that, but it is not just one Golgi tendon organ, it is multiple, is it not there are many. So, information is coming from many such Golgi Tendon organs.

So, also have been study. So, another way of representing the same data is that you know. If the muscle force is at some baseline level, there is going to be some baseline firing rate. For that, as the muscle force keeps increasing like that, you see that there is an increase of firing rate. As the muscle force is kept constant at a different level that is continued increased firing level here. And then as the muscle force is reduced there is a reduction in the firing rate.

So, then again once again telling us that you know this serves as a very good a relatively accurate force transducer. Another question is that going to be consciously sensed? Now, that means, can I say exactly how many Newton's is that; it turns out that the debate and the conscious proprioception versus a non-conscious proprioception is not yet settled.

At least in the case of the Golgi Tendon organs, this information is not consciously felt by the organism, how is it even being used what is the use of this. There must be some use, but when we say conscious perception we are not able to say I am producing so much force, whereas, in the length case it is useful to with the help of other receptors also. It is useful to come up with a body sense. Like where my body parts are.

Here in this case, how much force I am producing the people are not able to consciously say that. So, it seems are at least the current view is that at least in the case of Golgi Tendon organs this information goes to processing of movements future movements planning processing and correction of the present force product produced on the environment etcetera, but not necessarily on to the conscious level.

Let us this let us all this information go. So, far we have seen 3 cases we have seen the 1 a or the primary spindle ending. We have seen 2 or the secondary spindle ending, and then we have seen 1 b which is the which is the Golgi Tendon organ is it not. Where does all this information go? These 3 together constitute what are called as proprioceptors or some sense of body position or body's relative position, body parts is relative position with respect to each other right.

So, where does this information go. Depending on where this information is coming from they can go to several places. These pathways we will discuss in future, but at least I will just introduce in this class. Information from these we said that this is these are sensory axons, these are sensory neurons. Is it not we said that this information will go to the dorsal column? The neurons and the ventral side are usually the motor neurons the neurons, and the dorsal side are usually the sensory neurons. So, this information goes to the dorsal spinal cord, where in the dorsal spinal cord that is like saying this is going to some place in the body.

So, in the dorsal spinal cord there is nucleus called the dorsal nucleus of Clarke depending on again, this is depending on where from this information is coming, if this is coming from thoracic vertebra level 1 to lumbar vertebra 4 or 5. Let us remind ourselves the vertebral column and it is classification. There are 7 vertebra and this in the neck, these are called as a cervical vertebra. And there are about there are there are 12 vertebra in the thorax and about 5 in the lumbar region, and then depending on classification sacrum has sacrum is either one vertebra or 5 vertebra.

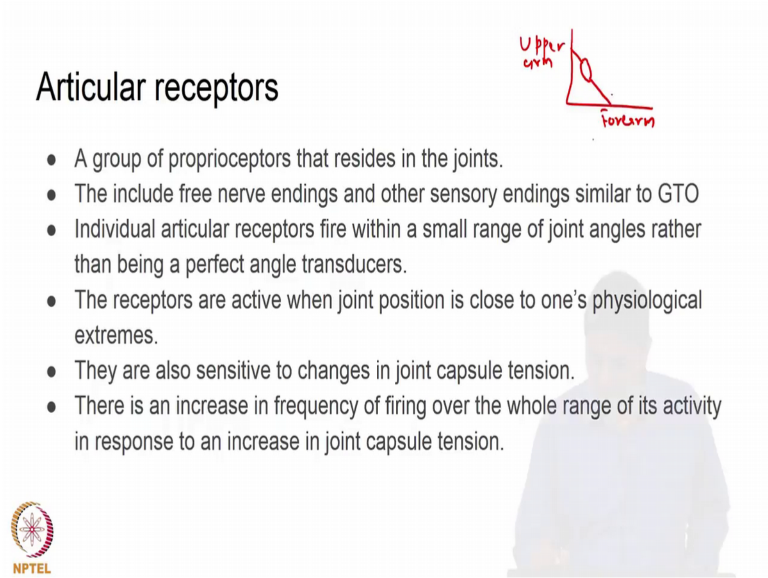
So, if the information is coming from T 1 to L 4 L 5, then it is going to the dorsal call nucleus of Clarke. And from there is a path that takes it to 2 places, one to the cerebellum. So, already we are talking about brain structures, I will be referring back to this in future, we will explain this function in greater detail in future classes. Information goes to 2 places, one is the cerebellum, the other is the primary somatosensory cortex. Taking a position on what is what in general it is believed that the when the information goes to the cortex it is more consciously perceived. And if it is going to subcortical structures, it is not consciously perceived. This is the general view although this view is being challenged.

So, information goes to the cerebellum via the spinocerebellar pathway ok. So, it also goes to the somatosensory cortex; where conscious perception of what is going on is going to be formed. So, there are so means, this information is branching into 2 places. One place where the action for depending on the input is going to be taken without regard to whether that is consciously approved or consciously acceptable. Another place where that is going to be consciously processed, and a decision may be taken, about whether that is. And if it is coming from about T 1 what happens? So, if the information comes from C 1 to C 7, 2 specialized nuclei called cuneate nucleus and gracile nucleus.

So, and then again this information goes back from these 2 nuclei this information goes to the cerebellum and the primary somatosensory cortex. So, this information again can be perceived. What is the pathway through which this happens cuneocerebellar pathway.

For example, in the case of cerebellum; so these details and these pathways which we will reserve for future classes. The point is that this information is going to higher structures through specialized pathways and there are specific nuclei that are responsible for relaying this information properly to specific places in the brain.

(Refer Slide Time: 13:14)

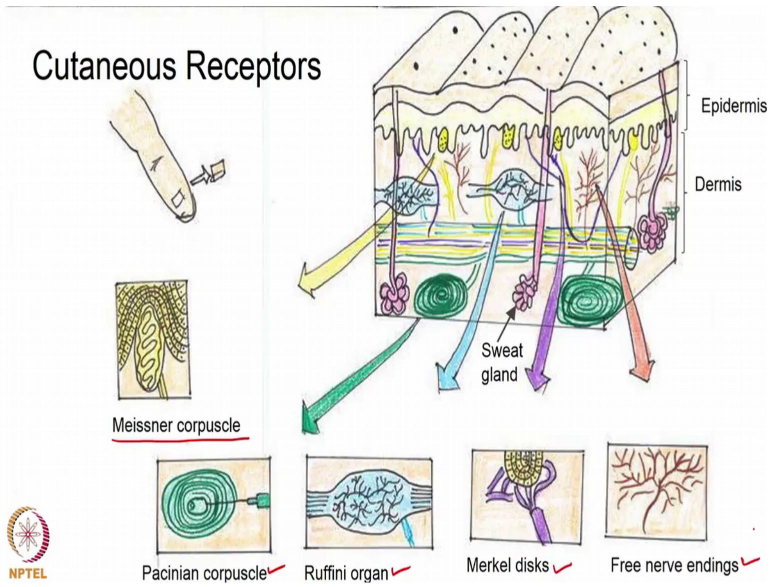


Then there are a group of proprioceptors that are believed to give information about joint angles. Why have all these length receptors these 2 length receptors in some sense is going to help me detect the joint angle is it not. So, if this is the elbow joint, say this is the forearm, this is the upper arm of a person and suppose that is the elbow joint. And if I know the length of this muscle, then in some sense I know what the joint angle is it not. If the length is say smaller, then the joint angle is different, or if I know the lengths of all the muscles that innervate this in that, that are attached to this joint. Then I can somehow we estimate roughly at least in some sense, estimate the joint angle. The goal is to understand how what the relative positions of the body is it not.

And in the case of the elbow joint, I can do that I can extend to this point, but beyond this point if I have extend what happens? It could cause an injury right. So, at these intermediate joint angles this sensor is going to be practically silent, but when I am at the extreme this joint receptors this sensor is going to start, you know making action potentials to warn the system somehow of impending danger you are at your extreme do not push yourself further in some sense.

So, that is the goal so, the physiological extreme. Only at the physiological extremes they are more active. We are not able to come up with a joint angle versus action potential curve in this case. So, they it seems like these are in some sense measure of joint angle, but how exactly they do that is still not understood.

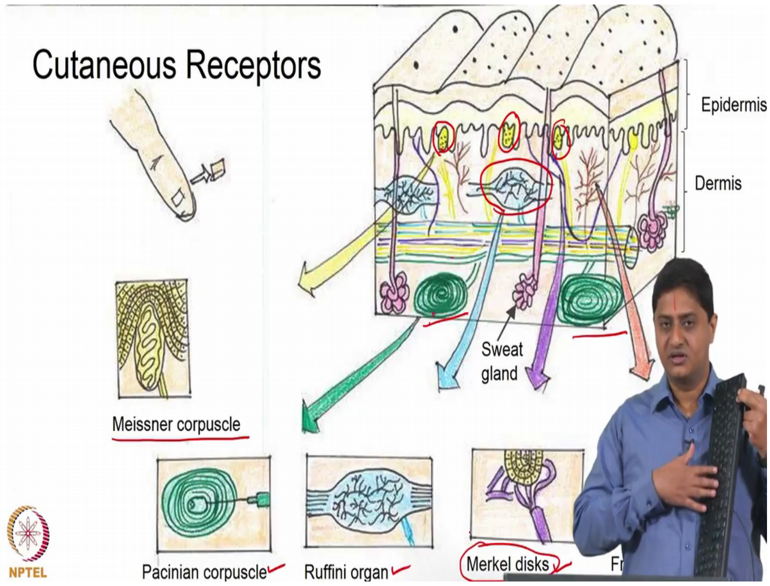
(Refer Slide Time: 15:11)



And then we have 4 receptors specially dedicated to hand and finger function right. These are Meissner's corpuscles, Pacinian corpuscles, ruffini endings and Markel disks. And then there are other free nerve endings and you know thermo receptors etcetera not mentioned. So, when you have so, in the skin, you have the outermost covering. That is the epidermis that by itself is composed of 3 layers. And below the epidermis is the dermis and below the dermis is the endodermis. And below the dermis you have these Pacinian corpuscles those that are in green here. And then there are these Meissner corpuscles that are here.

And there are ruffini endings here at the dermis and the region at that level and then there are this Markel disks. Why have so many? Because kind of things that we do with the hand and the fingers what are the kind of things? Several things right, we could move our fingers on a surface like that, and try and understand texture that is one, one thing, I can I can say this is a smooth surface versus taking this keyboard and you know and doing them relatively rough surface, right.

(Refer Slide Time: 16:39)



At least at least there are indentations at least there are structural ups and downs on them right. Another thing that we do is press hard on a relatively sharp object, when would we do that from time to time. For example, in the case of blind people reading with braille: for example. So, there are you know specific indentation specific raises in players in a particular spatial distribution helping them to read things so, that is that.

(Refer Slide Time: 17:18)

Haptic perception

Merkel Disks	Vertical pressure on the skin surface
Meissner Corpuscles	Sensitive to quickly changing pressure on a small area of the skin.
Ruffini Endings	Activates through larger skin areas and they adapt slowly and continue firing in response to stable deformation.
Pacinian Corpuscles	They react to rapidly changing mechanical deformation. (Vibration)
Free nerve ending	Pain and Itch Nociceptors
Thermoreceptors	Temperature

So, merkle disks are specialized for vertical pressure on skin surface. So, that means, they are going to be very useful in the reading of say braille. Why did I say this? Why did I mention braille, because it turns out that in the case of continentally blind people; people who cannot see from birth for whatever reason.

These individuals have increased sensitivity for these touch receptors. And that is that level of sensitivity a person with vision can never reach right. So, because our sense we depend more on vision for information. Whereas, the blind people because their brain they cannot depend on visions. So, their brain is adapted to sensing with these sensors more. And it has been shown that there is a quite bit of data showing; how this their plasticity at the level of brain using neuroimaging you said using different modalities at the level of structures in the brain there are differences between you know age match controls and congenital blind individuals and this so, while performing the same function while doing the same thing.

And Meissner corpuscles: in this case sensitive to quickly changing pressure. Ruffini endings again you know these are slow slowly adapting they are responsible for you know sensing larger skin areas, sensing over larger skin areas. And Pacinian corpuscles are rapidly changing; so for responsible for rapidly changing stimuli like vibration.

So, 2 of these are slowly adapting, 2 of these are rapidly adapting. Their functions are different, their differences in structure is due to the differences required in the function ok. So, this is the and then there are free nerve endings. And there are no receptors those that sense pain right. Those that sense pain are called as nociceptors.

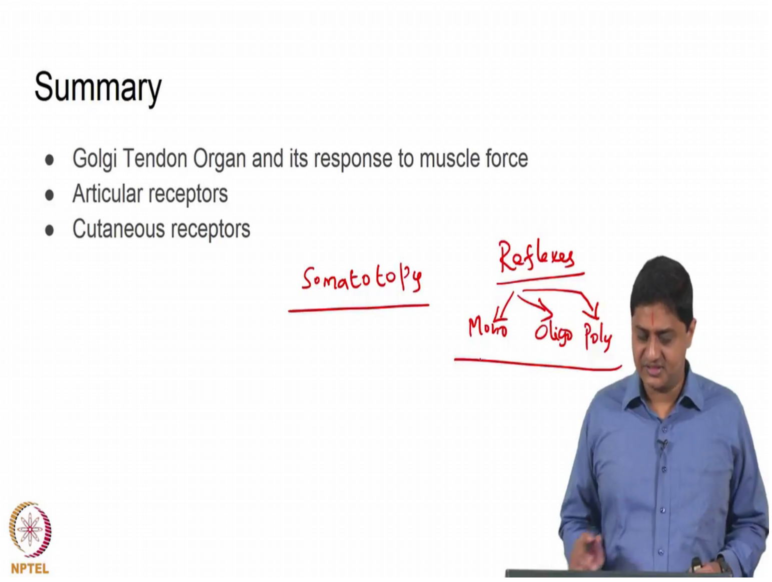
And those sense temperature there are more receptors. There are others that we are not discussing so much for the cutaneous receptors. Information from the cutaneous receptors is also used in controlling movements. Especially, of the fingers, because I have the fingers and how much the skin has deformed, depending that is one information at least one source of information for controlling finger movements. But that is not the only source. Obviously, there are proprioceptors of the muscles that control the finger movements. But the fingers and hands also are bestowed with these high quality receptors sensors that are responsible for sensing a whole number of things.

Know that there are only 2 parts in the body, 2 specific areas within the body where there is a high distribution of sensory receptors. One is the hand or the hands 2 is the lip and the mouth area right. By the way there are reasons why these 2 evolutionary reasons why these 2 must be important right. Because I am at least evolutionarily when I am trying to pick up an object I need to examine what this object is try to come to terms with whether it is, let us say it is thorny it is a thorny fruit. What is inside is useful, I mean I like to eat it, but you know I cannot just put it in my mouth.

And that is also sensed by the lip like, what goes inside is in some sense controlled by the lip hopefully. So, which is why we like smooth things rather than, but nobody likes to eat a sharp thing right. So, that is the reason we rise we like a ice creams.

So, anyway that is with haptic perception.

(Refer Slide Time: 21:32)



So, what else? So, in summary we have seen Golgi Tendon organ, which is a nearly perfect force sensor or a tension senses. It is going to sense how much tension is there in the muscle. And joint articular receptors, these are believed to be sensors of joint angles at least in the extreme positions. It is not clear what their function is or how if they are present in all muscles it is their more needs, more information more research needs to be performed to understand their function better. And then there are cutaneous receptors. These are Pacinian corpuscles Meissner corpuscles Markel disks and Ruffini nerve endings. And other things such as nociceptors thermo receptors, free nerve endings and such.

So, all this information goes to as I as I said goes to the either to the dorsal nucleus of Clarke or to the gracile and cuneate nucleus and from there it goes to the somatosensory cortex; where it is in some sense um, where sense is made out of what that our conscious perception is happening in the somatosensory cortex. It turns out that how do you know by the way, how do we know where the information is coming from? If the somatosensory cortex is receiving information from a whole bunch of body parts is it not, it is receiving from all the fingers, and hand it is receiving from the rest of the body it is receiving from the legs also.

It turns out that there is within the somatosensory cortex, there is a map of which area is responsible for receiving information from which body part. So, this type of a somatic map or a body map also called us this feature, for body map within the somatosensory cortex and elsewhere. So, a body map within the brain is also called as somatotopy. So, that using that, there is this information, that is sensed.

So, with this we will come to we will stop this class with this and we will see in future classes. The following topics reflexes; how these proprioceptors themselves cause reflexes. And what are the various types of reflexes, so monosynaptic, polysynaptic, oligosynaptic, etcetera. And what are the mechanisms of these reflexes are movements, reflexes maybe movements. So, our response of the body to specific stimuli; how these are controlled.

So, with this we will stop this class.

Thank you very much.