Virtual Reality Engineering

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Lecture - 68
Human Haptics - Tactile System

Welcome back. So, in the last few classes we have been looking at the haptic system. We have looked at the haptic system is a combination of sensory system and their motor systems together. In the previous class, we looked at the psychophysics of the perception touch specifically.

Today, we are going to be look at sensory part of the haptics specifically we are going to focus on tactile part of the haptic sensory part also. We have seen in the last class it has a four modality tactile system, kinaesthetic system, thermal system, and the pain systems right.

We are going to focus on the tactile systems in today's class we will look at the skin aesthetic system in the next class. Let me start with the basic question. How many of you seen skin? How many of you have seen the skin? The yeah question seems to be now irrelevant right or there is a trivial is not it.

Student: The skin of animals.

No, it is your skin; Have you seen your skin? That is the question I am asking you. So, that question seems to be trivial, but it is not trivial, do we know what is our skin?

So, apparently now what you are seeing is not the skin which we are going to see ok, skin is beneath the outer skin; we will see it. So, essentially we are going to talk about yeah entire process of when touch happens on the skin.

What are the things happening in the central nervous system and then what happens until the brain systems.

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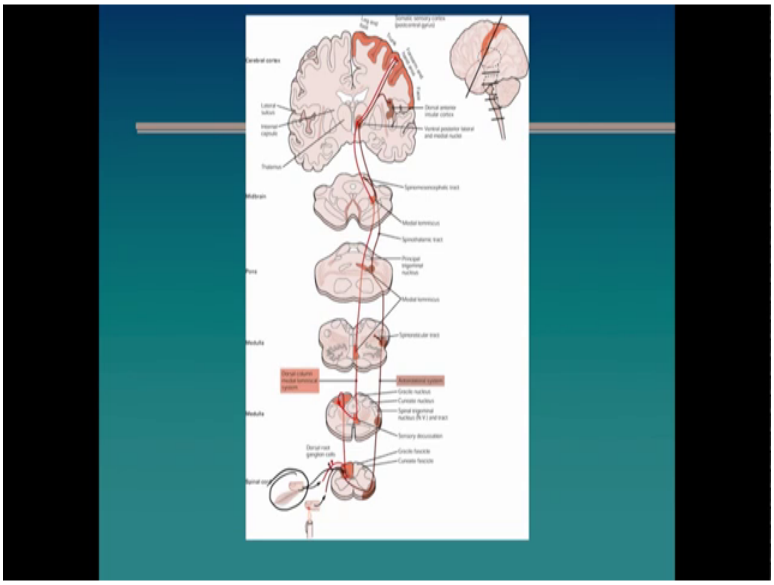

So, for example, here we are talking about the fingertip when fingertips touches something. What is happening in the fingertip? How the signal or stimulus is converted into electrical impulses. And then how it is conveyed it to the central nervous system and what are the different processes happening; until their nervous system is what we are going to see today

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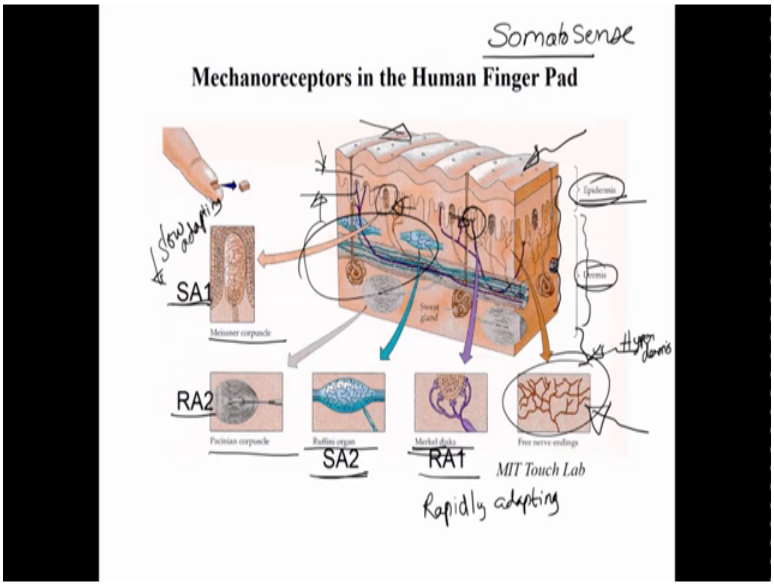

We will start with the answer to the our question. Have we seen your skin? Ok apparently you might have seen it unless you are a doctor where you do the you know surgery. Our skin is about a 100 micron beneath the apparent cover.

So, what you are seeing outside is actually a dead layer of your skin that is not your skin at all it is called the Epidermis. The dermis the skin which is over the skin the cover is what yours what is what you are seeing it. The real skin is buried underneath about 100 microns below that is called the Dermis that is a Greek or Latin name in it.

So, this part is the skin ok, the skin is where there are a lot of sensors over there. So, we are going to see specifically some four different sensors. This is the Merkel disc is one of the sensors, Merkel disc skins are there over here.

So, you have seen your fingerprints under the fingerprints there are ridges what your this is a along zoomed is this is the fingerprint ridges.

Under the ridges there are sensors there very small sensors that is called the Merkel discs, this Merkel is named after a scientists who has invented that in a about 150 years ago, it is a German scientist, it is called a Merkel disc.

And then there is other meissners corpuscles again between those ridges there is a another sensor meissners corpuscular, we are going to see that details of this. And then there are Rufini organs and then Pacinian organs.

So, you can see that this sensors are embedded in different levels, different depth of the our skin. So, the Merkel and meissner you can see that it is in the top layer of the skin, the pacinian and rufini they are in the bottom layer of the skin.

There are little deeper they are not at the surface level by the way do we know why we have the fingerprints? Unique identification, is are the reason fingerprints are unique, but why we have this fingerprints.

Student: Grip.

Grip alright. Is there any other answers?

Student: To hold the sensors.

To hold the sensors, objects that is what a grip he was talking about ok. There are some researchers recently they looked into the fingerprints why we have the fingerprints. Some people say that at the fingerprints enlarges the any stimulus, amplifies the stimulus.

So, that the sensors here actually now, gets a better signal to noise ratio is improved or whatever it is. But still it is inconclusive why we have their fingerprints you can go back and look at the literatures still scientists do not have clear cut idea why we have the fingerprints ok.

One of you can become a scientist in a haptics. And then you know tell a reason confirmed reason that this is the reason we have fingerprints it is still a open ended research question.

So, this numbers this names and the numbers we will have to now get familiar with we are going to use it again and again throughout the course ok.

They are also named as now SA 1, SA 2, RA 1, RA 2. SA 1 is for slow adapting they are going to see the reasons for or this naming slow adapting. This is slow adapting 1, this is slow adapting 1, this is a slow adapting 2, this is a rapidly adapting. See why it is called the slow adapting why it is called rapidly adapting we will look at it in different details.

So, below that dermis part of it I told you this is the real skin; below that dermis part of it there is also called the hyper dermis, where there is a lot of fats and everything is there. This is about you now 1 mm that is all right and there are a lot of fats over here. This is a representation of the skin.

In your fingertip if you take a small section of the skin from any other parts of the body it is going to be entirely different ok. The thickness of this outer layer is going to be different; the thickness of the dermis layer is going to be different ok. And then the hypodermis layer also is going to be different.

So, the cross section is varied throughout the body why should it be why cannot it be the same everywhere. The skin gets adapted to depending upon what is required ok, because we have going to end up touching many objects very regularly very often.

So, the nature has put up lot of sensors over here at the back of our back we do not need a lot of sensors we do not use our back to touch many of the objects. So, we do not need many sensors at all. So, the skin cross section is vastly different that is one reason.

And yes when we take bath what happens is this is outer layer, this is a epidermis they sheds off the layers, when we take bath the dead cells are washed away that is one of the reasons we have to take bath very regularly ok.

You know one of the main reasons of our skin is not only to protect, but also to cool our body. So, when you take bath the body gets cooled out this way cooling the body is a secondary purpose of for organ every organ has a secondary purpose.

So, eyes is only for seeing that is a primary purpose it has a secondary purpose, liver has one primary purpose and secondary purpose for many of the organs we have not even found out what is the secondary purpose. So, researchers are still looking at now what are the secondary purposes. So, many of the organs we have we only know what is the primary purpose ok.

According to our Indian literature the skin is looked at you know in much more deep. So, whatever I presented now is the is a understanding of the modern sciences of today.

But our system there is a Indian medical system called Ayurveda, how many of you heard about it right ayurveda, Siddha, in southern part of that is specifically in Tamil Nadu, and Kerala.

There is a system called a Siddha medical system and there is a Verma medical system there the skin is looked at you know in much more details and the top layer itself is divided into 7 more layers ok.

Epidermis itself is divided into 7 more layers and then each of the layer is connected to Pancha Boothas; Pancha Bootha so that is our typical Ayurveda science which we will not get into details.

But I just want you to you know remember that our Indian science has much more details than the modern science. We will not go into that Indian science about it this course concern only the modern size, but any of you who are interested you can get in to the Indian science.

And look at maybe some of our findings in the Indian science could be you know could be elucidating some details in the modern science alright. So, this corpuscles this mechanoreceptors we call all this in short mechanoreceptors.

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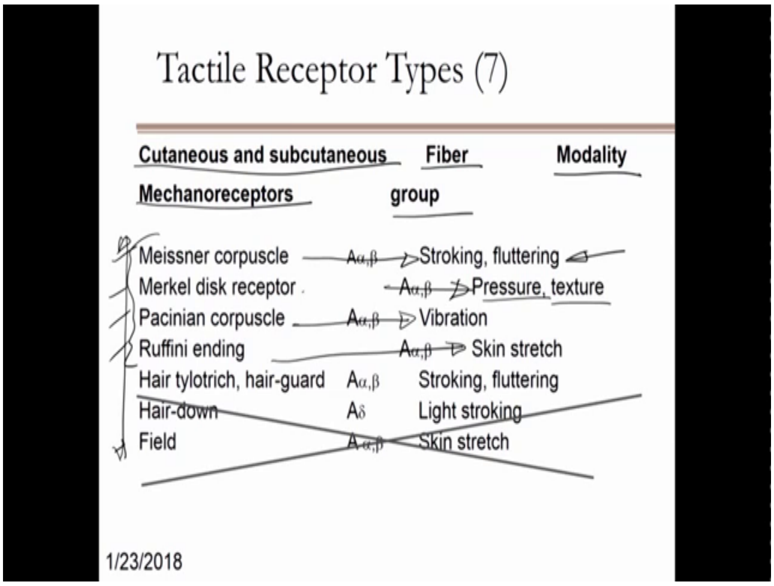

Specifically cutaneous and subcutaneous mechanoreceptors; So, these are the different names not only the 4 mechanoreceptors, what we have seen meissner, Merkel and pacinian ruffini.

There are also another mechanoreceptors for example, this is also nerve endings. If you look at your air loops air loops does not have any of this 4 mechanoreceptors does not have any of this sensors.

But still we find it now sensing our touch, I am using the pen if you use your finger probably the sensors when your finger may be sensing the forces right. If you use your pen or a pencil and then try to stroke your ears you can see that you still get sense of touch how is it?

There are very small nerve endings over there and then nerve endings since a see touch ok. These are all specialized receptors whereas, a nerve ending is a very basic receptors are you aware that now the blood vessels has the sensors entire blood vessels even the minute blood vessels has the sensors mechanoreceptors.

So, essentially entire body is full of mechanoreceptors, entire body is full of the start end receptors touches your bodies and it is called a Somatosense. Have you heard about somatosense? Somatosense somato means body bodily senses.

The entire body is made up of the touch sense other sensors are just located in certain parts of the body it is all now restricted to certain are not an average the somatosense the touch sense is there throughout the body.

So, when you and I were in the mother's womb the first sense developed is the touch sense, there is a body sense, that is throughout the sense, only then other senses started developing that is one of the reasons we call touch sense as a fundamental sense without the touch sense other sense cannot be developed at all.

So, we will find the details of this sense in the coming days. So, each of the sensors are also having a different nerve fibers we will see. But the modalities is what is what is it is a sensing each sensor is a specialized sensor it is specializing for certain stimulus energy ok.

So, for example, meissner if you look at it is sensing the stroking stroking is a very slow on a movement and then fluttering is a very slow vibrations ok. Merkel is sensing the pressure and then texture your shirt is applying a certain pressure on your skin and that is actually felt by Merkel you may not you know realize it all the time.

But when you start giving your attention you can see that the shirt is applying a certain pressure on your or body that is sensed by the Merkel receptors. Pacinian it is sensing the vibration from a few hertz to 1000 hertz it is sensing the vibration.

Ruffini endings it is all sensing the skin stretch when the blood vessels is now increasing in the volume it is gets stretched that is sensed by the rufini endings ok. There are other sense also, but what we are going to do is we will focus only on these four things.

Whenever we say mechanoreceptors we will remember this meissner, Merkel, pacinian, and rufini endings ok.

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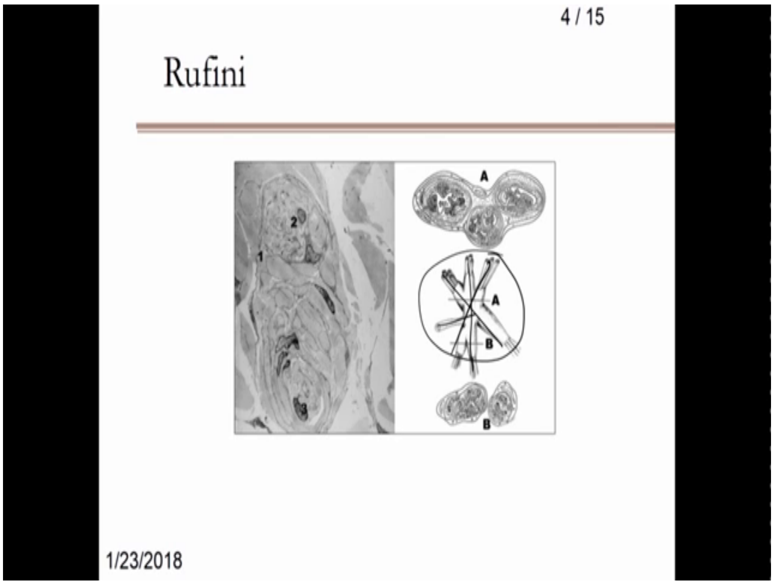

People have looked at the cross sections of each of the sensors and then given you the diagram of these things. So, if you look at the rufini disc it is something like this it is like a you know body where there are cross sections of different endings are going over here ok.

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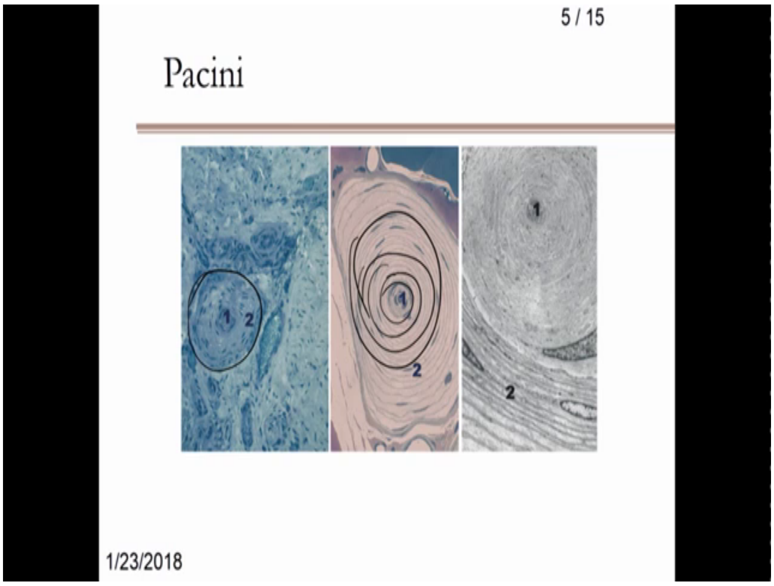

These are the rufini discs are this is the pacinian pacinian is the one which is sensing the your vibration and all your stomach has this pacinian receptors. It is sensing these slow movements to now very frequency high movements.

You can see that there are layers, layers, and layers of and our tissues around the sensor and these are all very important. We are going to see how each of this sensor is actually transacting the stimulus to the electrical impulses ok.

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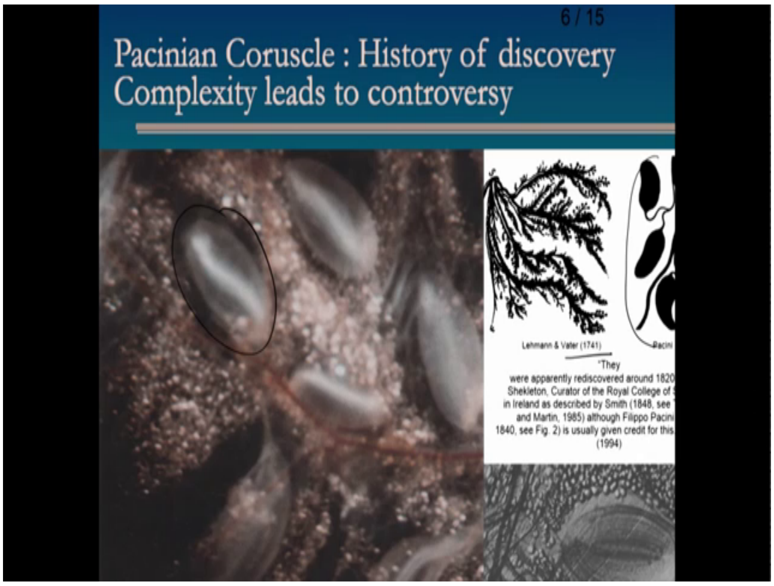

You can see that at one of the recent photographs of our pacinian corpuscles ok. You can see it is like almost like you know does it look like a what which one.

Student: Beans.

Beans alright, grapes or beans it is a bunch of grapes sitting together, it is a very zoomed version of it and each one is about less than you know 200 micron ok.

There all bunches of the of this receptors are over here by the way this is receptors research has started 300 years ago not recent people have been looking into this receptors for last 300 years. But still there is there is so much of information which is not there.

So, some of you I hope will become a researchers and the elucidates some of the missing information.

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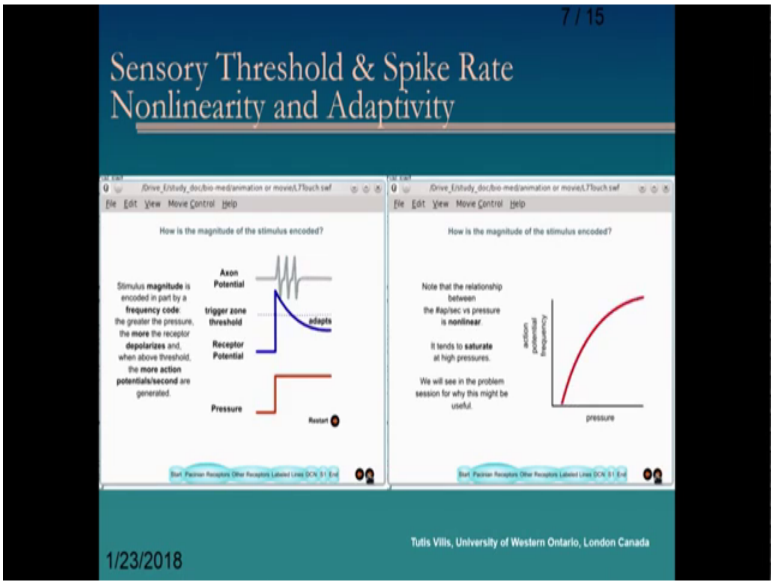

So, all this four receptors even before coming to I want to show you this ok.

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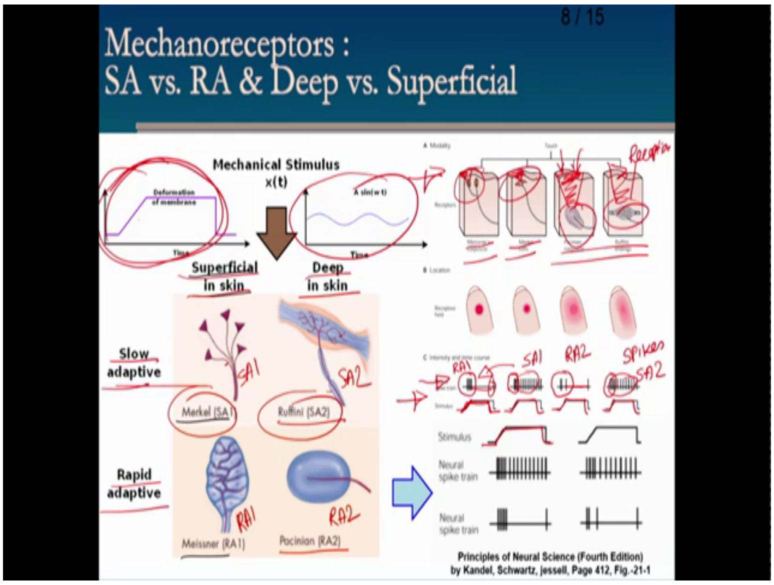

So, we are talking about two kinds of receptors superficial that is on the surface level. They are the Merkel and meissner let me pick up a different colour pen. Merkel and messiner they are superficial skin receptors.

There are deeper skin receptors they are rufini and that pacinian all these names you will get familiar with that. So, we are going to called a slow adapter sensors as one in the super skin superficial in the skin and the another one in there deep in the skin.

These two are slow adaptive this is called the SA 1, this is called the SA 2, and then rapidly adaptive this is called the RA 1 this is called the RA 2.

So, you can see that in this diagram meissner and meissner and Merkel both are in the superficial the region. And then pacinian and rufini they are all in the and the a deeper in the skin.

So, why is it called slow adaptive? Why is it called rapidly adaptive? This concept is very important for understanding the entire neuroscience part of the haptics.

So, pay attention suppose if we give a stimulus of this region (Refer Time: 19:51) stimulation (Refer Time: 19:54) and whole that is what is call over it. Let us say we give this stimulus to each of these receptors what happens let us look at over here.

So, in meissner if you look at this (Refer Time: 20:07) what happens is only when there is a change there is this electrical impulses. All these receptors converts stimulus into electrical impulses ok.

This is let us say this is the output of each of the receptors and these are all electrical impulses let us called that as spike, spikes, electrical spikes.

So, you can see that whenever there is a change in the stimulus there is a spikes when there it is maintaining when you are holding the (Refer Time: 20:53) and hole there is no spikes at all ok.

Again when there is a change there is one more spike over here. So, what is actually happening it is adapts to the stimulus only when there is a change it is actually generating in the impulse ok. It is like a differential sensor right if you look at the other one that is a Merkel for the same (Refer Time: 21:19) you can see that when there is a change there is more spike when there is no change there are lesser spikes.

So, unlike the earlier one it is not completely stopping the spikes this is called the slow adaptive SA 1, this is called the rapidly adaptive RA 1 ok.

Similarly if you look at the pacinian again whenever there is a change alone it is there are spikes whenever there are no change there are no spikes at all this is called the this is called the RA 2 and this is called the SA 2.

The last one is the rufini endings again you can see that there are more spiking when there is a change there are less spiking when there is no change. So, this classification of the receptors into slowly adaptive and rabidly adaptive is very important as far as the neuroscience aspect of a haptics is concerned ok.

So, again this is explained in this stimulus spike train this is this is for the more 4 of 4 receptors it is given over here ok. Now, instead of changing the instead of having a (Refer Time: 22:53) and whole we can give a now sinusoidal input how would it how would their receptors respond to the sinusoidal input.

So, there is again and can be looked at, but ramp and hole gives you an idea about what is slow adaptive, what is rapidly adaptive ok.

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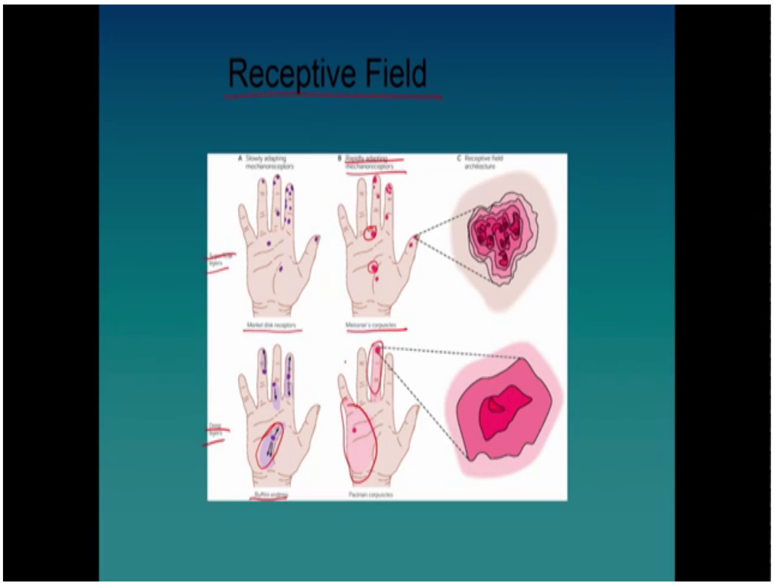

And each of this receptors has a property called receptive field. They are responsible, they will respond when their stimulus is present within certain field that is called the receptive field ok.

Each sensor has a different different receptive field and knowing what receptive field held for what mechanoreceptor is very important. Specifically logically if there are superficial skin the receptive field could be very very less.

So, if there are superficial skin then their receptive field is could be within this region it could sense whenever there is a stimulus.

Similarly here also the receptive field can be very small, but when there is a deeper sensor it is receptive field has to be very big right.

So, whenever there is a signal anywhere here this sensor will respond to it, similarly this also it will have a different receptive field. So, the concept of receptive field is another important concept you need to learn so that is what is shown over here.

This is a superficial sensors these are all slowly adaptive mechanoreceptors, you can see that Merkel has receptive fields this purple coloured marked is a receptive for field for each of this Merkel sensors.

And for rufini you can see that since it is a deeper receptor the receptive field is actually bigger larger alright. Similarly rapidly adapting if you look at it and the sort of meissner corpuscles which are superficial it you can see that the receptive field is very small.

And for the pacinian you can see that it is a deep sensor, rapidly adapting and then receptive field is very very large ok. Depending upon the receptive field whether it is a superficial or deeper the number of sensors also is different.

The number of sensors each of this sensors in is different for different parts of the body again it depends upon the requirement.

So, in some places where pacinian will be more in some other site anatomical site it Merkel will be more it depends upon the requirement.

It is highly adaptive when you when you your skin required certain particular stimulus as adaptation; then the number of particular sensors grow up increases or decreases nothing is constant ok.

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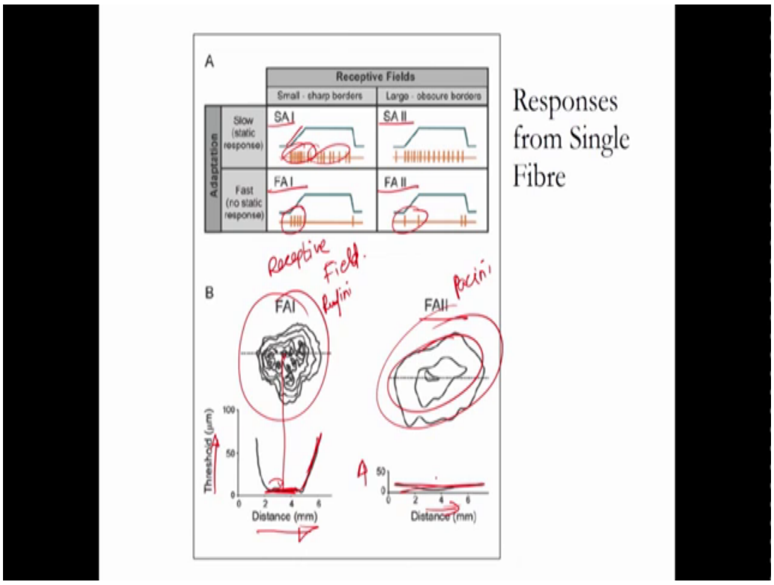

The same information is shown over here a slow adaptive SA 1, and SA 2. You can see that the spike trains are increasing decreasing according to the requirement.

Whereas, the rapidly adapting in some literature it will be also called the fast adaptive, rapidly adaptive, fast adaptive. So, do not get mixed up FA 1 and FA 2 you can see the spike trains or getting adapted to it ok.

And this is shown the threshold and in this graph it is not the threshold it is actually it is showing the receptive field right. So, the receptive field is shown in a graph over like this, the y axis is the threshold, in the last class we saw the concept of threshold which is the fundamental for psychophysics right.

So, what is the minimum pressure required for the sensor to respond that is the threshold right. So, if the stimulus is within this particular range say let us say this is centre of the fast adaptive receptor.

Then and then the threshold required for the stimulus to make the mechano receptor respond is actually very small. If it is more then it requires very high threshold ok.

Similarly, this is the FA 2 fast adaptive adapting 2 this is the rufini and this is the pacinian. You can see that this is a receptive field and the distance and required or the threshold required or with a distance is almost constant for a FA 2 RA 2.

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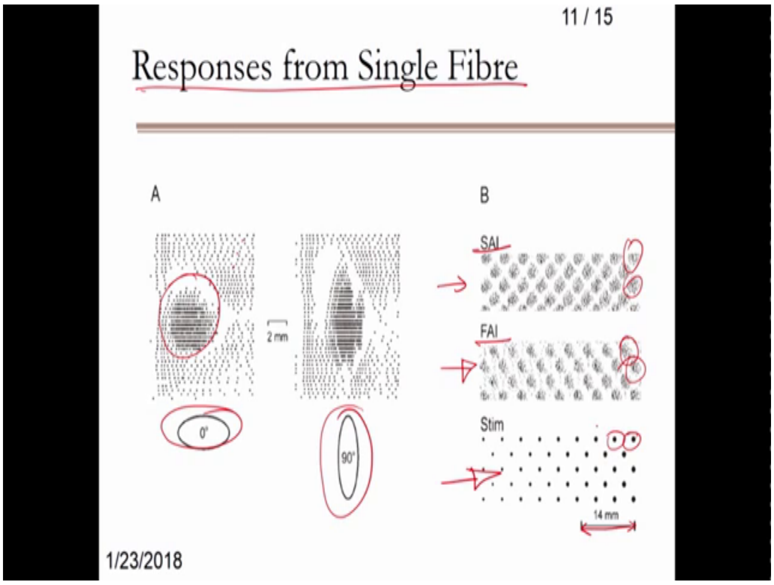

This receptors also encodes the shape so, in the earlier slides what we saw that the receptors encodes a stimulus right so they also encode the shape of the object.

For example, if I have a ellipsoid objects like this let us say if this is a 0 degree, there is a ellipsoid object in 90 degree the responses from this receptors is actually now capturing the shape of the objects.

So, these are all this dot dot, dot, represents the responses from a single fibre, each of these fibres, imagine that each of the neuroscientists actually neurophysiologist they cut open the finger or attach the electrodes to each of these receptors.

And then look at the how the electrical impulses are coming out and that is what record over here each dot represents the presence of the electrical impulses. So, you can see that this responses from each of these receptors it is actually including the shape of the objects alright.

So, in the right side of the picture you can see that if this is the stimulation the dots are you know the distance is the 14 and mm of within this range.

You can see that the stimulations in area is actually slowly increasing you can see how FA 1, and the FA 2 is actually responding ok. Again it is captures the stimulation location.

And the intensity of it you can see that as the intensity of this stimulation say increases this more and more receptors also increases. There is only FA 1 and FA 2 you can see that at the dot diagram for each of these receptors actually it is growing bigger that shows that at it captures the location as well as the shapes.

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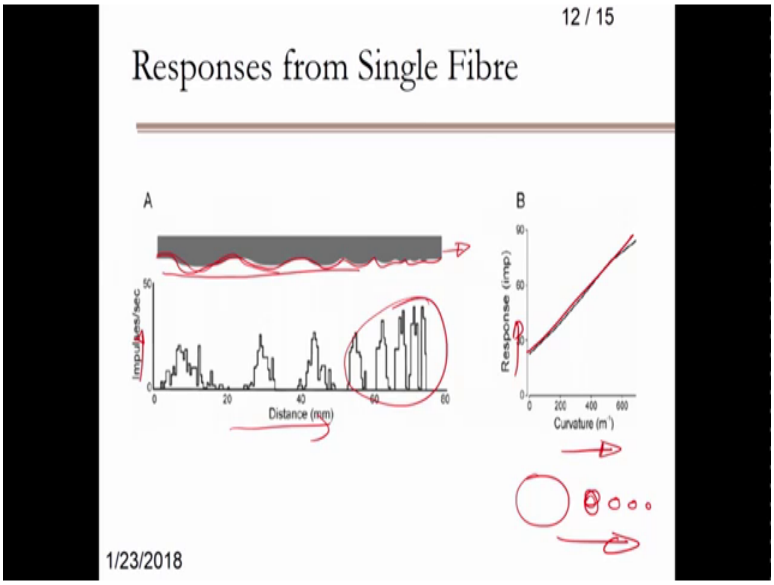

Again if you look at a and as stimulus which is varying in a in a in the shape let us say it is a so, wavy the waviness is more initially as we go the waviness is increasing.

Waviness is in lesser over here the frequency is lesser and as we go the waviness increasing as it increases you can see that impulses responses from the single fibres is also increasing. As a waviness increases the responses also increasing it is capturing the shape that is what as meant over here.

The curvature of an object for example, if you have the spherical object or cylindrical object now as the curvature increases let us say curvature we have we are increasing like this more and more curvatures.

And how their responses changing over here you can see the linear relation between the curvature as well as to the responses ok. So, the mechanoreceptors encodes shape curvature the waviness location. There are so many things at the end of this class we are going to see what are the different properties of the stimulus this mechanoreceptors are capturing.

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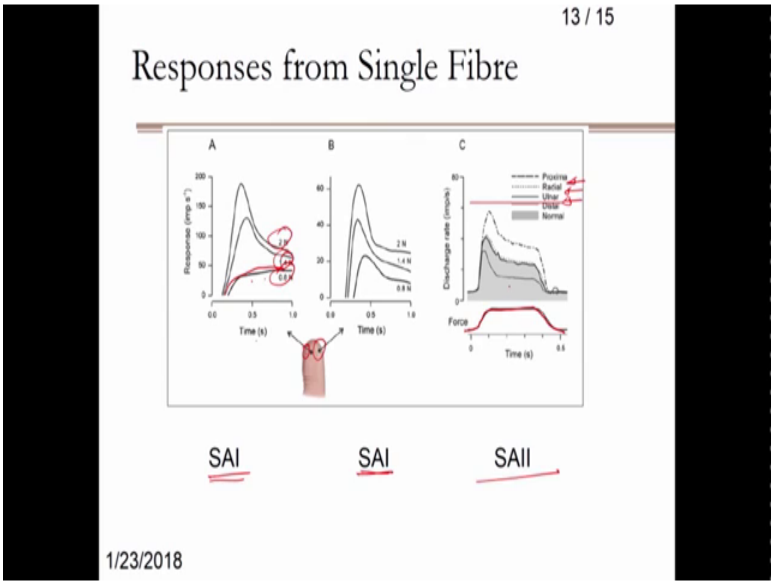

This is again and how SA 1 is capturing the responses with respect to the time. This is for pressure different pressure how the SA 1 is the same SA 1 this graph as well as this graph, it is responding to pressure or a force.

But two different sites when the stimulus is over here; how is the response you can see that at 0.8 Newton it is like this is 1.4 Newton is like this and then 2 Newton it is like this, slightly different how this force response is actually changing depends upon the location.

This is how the mechanoreceptors captures the changes in the location this is a SA 2 the same thing this is capturing the force, this is a input force a ramp and hole and these are the responses from different sites. You can see how it is changing over here.

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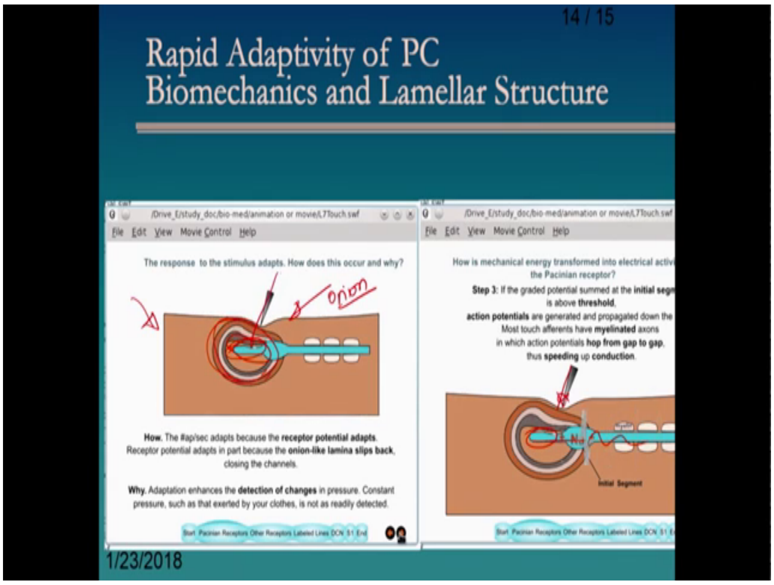

Pacinian receptors as you know it is a rapidly adapting receptor. So, how does it rapidly adapting it here sensor. So, one of the very nice thing to put it very simply it is like a the pacinian receptor has a onion like structure.

Let me put it as a onion like structure if you cut open an onion you can see the layers of layers and layers. So, the layers are tissues in between the tissues there are liquids field over here.

So, you can see that for example, it is just given two layers alone in between the liquid is shown here is the like yellow colour, this is a red colour just to show you that there are liquid layers.

So, when you apply when the stimulus is applied you can see that each layer is sliding over the other layer. Because there is a fluid field in between unless you rapidly apply the stimulus is rapid enough so that the viscosity of the liquid does not allow the outer layer to slip with an inner layer.

The stimulus will not reach the core of the receptor. This is the core unless this stimulus reaches the core it is not going to generate electrical impulses.

So, for or the structure onion structure of the pacinian in such a the way that below a certain frequency of the stimulus it will filter out it will not, let the stimulus reach the inner neural core.

Only if it reaches a beyond certain frequency this will reach there the innermost neural core. Then once it reaches the innermost neural core it will start generating the impulses ok.

So, there are pacinian corpuscles with 100 layers, there are pacinian corpuscles with the two layers. Again it depends upon the sites how much is each of the layer thickness our lab has modelled each of these layers and from one layer to next layer how this signal is actually translated.

So, entire thing is actually modelled ok. There are anatomical data is available there is a anatomical data as using the anatomical data we have accurately modelled the pacinian receptors. So, once the stimulus reaches the core then it starts generating the electrical impulses.

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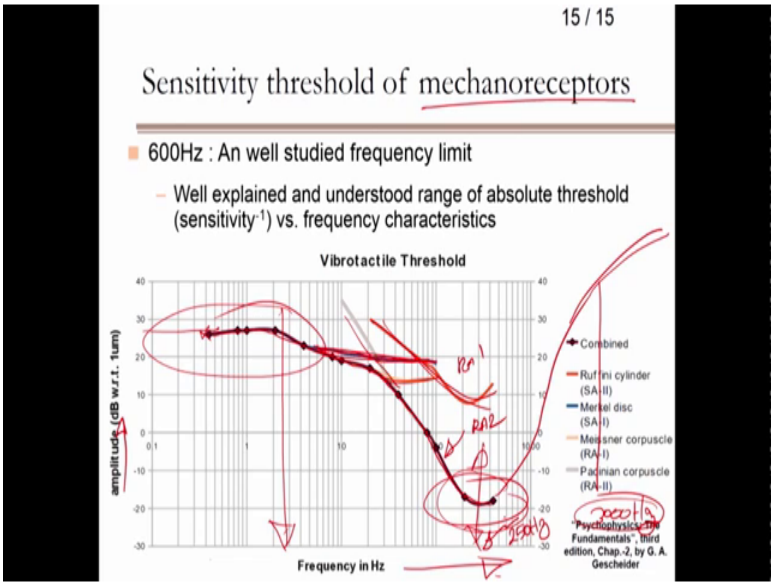

So, one of our current PhD student is developing further models and simulation of this pacinian corpuscles our TA. He is looking at now distribution of all this sensors, how it is actually encoding the shapes or other our information from our stimulus ok.

And this pacinian corpuscle has certain and very unique responses. For example, if you increase the frequency of this stimulus; basically tapping increase the frequency of this stimulus how much is the minimum amplitude needed for this pacinian corpuscle to respond that is plotted in the y axis amplitude, that is basically a threshold alright minimum amplitude is required. So, that is plotted over here.

At very low frequency this is the log scale very low frequency the amplitude required is about 20 micron, it is in the in a decibel unit it is given. You can see that as the frequency increases it is the threshold required is actually reduces.

You have your cell phones the cell phone has a vibrator; when you hold your cell phone in your hand what is actually being sensed is by the pacinian receptors ok. If your cell phone vibrated is having lesser frequency then your cell phone vibrator has to a has to have a amplitude which is which is much more over.

If the same cell phone vibrator has a frequency which is at this range then the amplitude required for your hands to sense is very less ok. This frequency is about 250 hertz ok. And as you increase it increase the frequency it again increases it is not staying over here.

As you increase the frequency about 250 hertz, the amplitude increases and it reaches very high. At a very high frequency you need a much more threshold for you to respond. So, 250 hertz we want very good vibration sensation then you will have to operate at now 250 hertz ok.

And not only pacinian response to this particular vibration there are others also for example, the other coloured graphs also there they are also responding to it, but at you can see this is almost constant let us say SA 1, this also is almost constant this is a this is SA 2, and this is RA 2, RA 1, this is a RA 1, what this is one is the RA 2.

So, every sensor response to the stimulus, but one sensor is specialized into it is it is not that you know only one sensor will respond to a particular stimulus it will respond but now only one is specialized in to it this you need to you know keep it in mind.

And we have measured this responses of this threshold beyond 250 hertz until 3000 hertz we have measured and we found that the threshold needed at 3000 hertz is very very high.

So, there is a first time we have measured first time yeah frequency of 3000 hertz is reported for you know our pacinian mechanoreceptors are reporting the threshold of our pacinian receptors.

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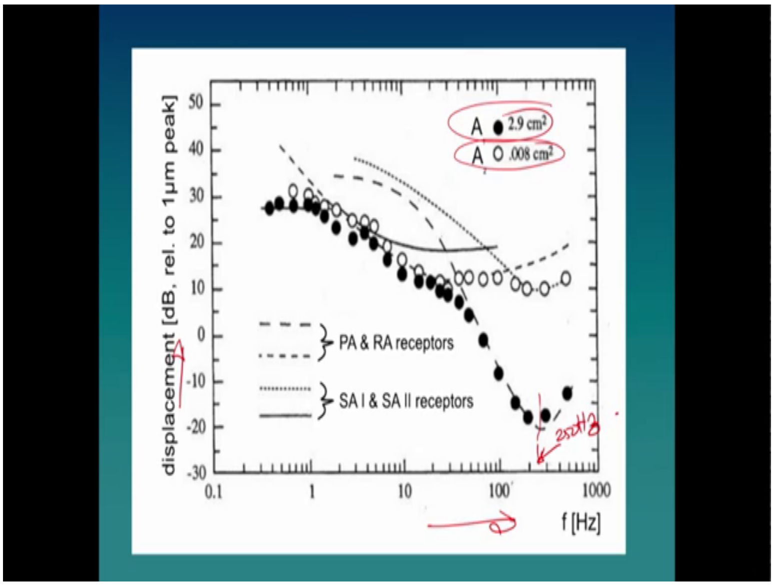

So, the same graph is mentioned over here you can see that this is about 250 hertz and this also plots different area, for a different area the receptors responds differently.

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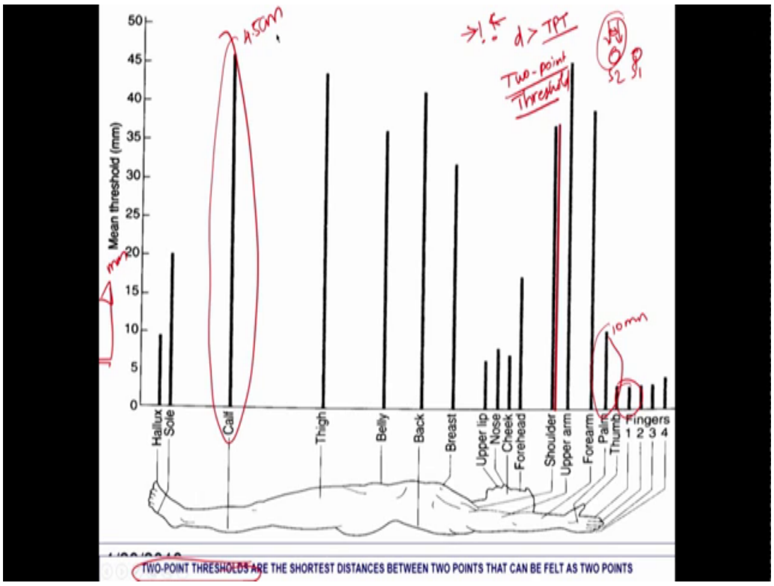

This is the amplitude, displacement, is given over here and this receptors as I mentioned earlier it has different distributions throughout the body.

So, how do we measure how much is how much is the how is a distribution of the sensors in our body. There is a very simple measurement this measurement is called the two point threshold measurement.

Two point threshold means suppose if I give you two stimulus how will you be perceiving these two different locations yes, but only if this distance is greater than some distance; d should be greater than two point threshold.

If it is below there two point threshold basically you have a two two different sensors if the stimulus is the you know lesser than this two different sensors there is a let us say s 1 and s 2.

If the stimulus is distance is lesser than this sensors distance then you will not feel that as two different stimulus you will feel as only one stimulus that threshold is called the two point threshold threshold right.

So, basically take a small campus whatever you are used in your geometry box in your schools. Now, separate the prongs of the compass and position on your skin and keep varying the distances at on which distance you feel two points that is what plotted for different sites over here.

You can see that for the fingers it is very very small the y axis it is mentioned as mm it is about in a 2 mm or 3 mm the finger even more finer ok, for the palm it is about 10 mm.

You can see that the highest is in your calf you know how much is it is 4.5 centimetres, two different points below 4.5 centimetres cannot be perceived in your calf muscles; that is because the distribution of these sensors are very very less there whereas, finger it is very high.

Again it is a natures choice wherever this is a much use now nature has put in more sensors; wherever there is a less nature is you know optimizes ok. Because all this sensors have to be connected back to the brain, it does not need an unnecessary circuits going to the brain right that is the one of the reasons.