Basics of Mental Health and Clinical Psychiatry
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Lecture 28
Physiology of Sensations

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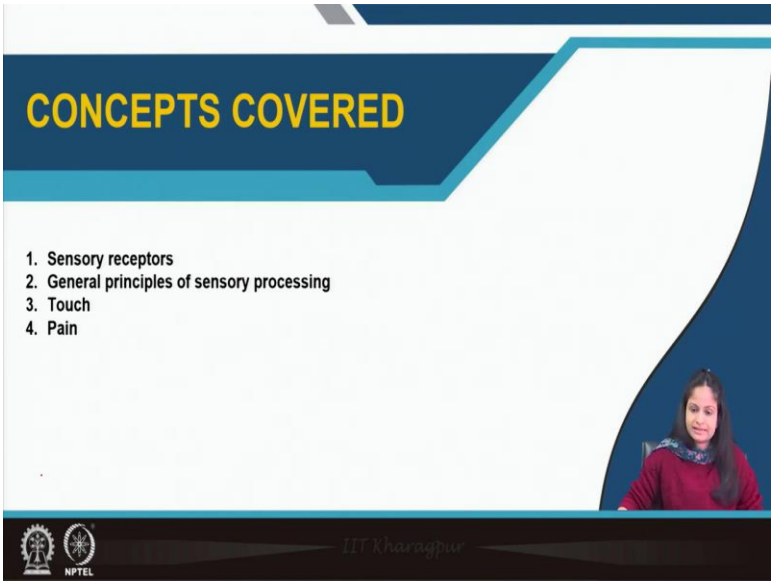

Hello everyone, so we will start our next lecture that is Physiology of Sensations. Here we will cover various sensory receptors, the general principles of sensory processing, and mainly will concentrate on the touch sensation, and the pain sensation.

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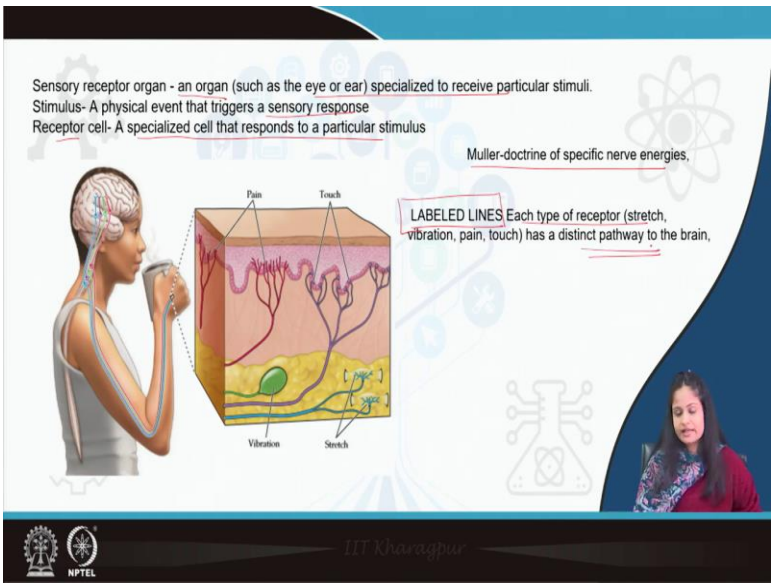

So what do you understand by sensory receptor? A sensory receptor or this receptor organ various receptor organs like eye, nose, ear these are the receptor organ, these are specialized to receive particular stimuli. The stimulus is a physical event that will trigger a sensory response and to this sense, to this stimulus the cell which will respond that is a receptor cell, a specialized cell that responds to a particular stimulus.

So in our body there are various types of receptors. Now before that molar has proposed long ago a doctrine of specific nerve energies. Now this this proposals was given before the discovery of action potentials. It was proposed that the various sensations in our body are not carried all together by one single track but or one single energy, we have different energies for different sensations.

Later on we have come to that the various ex, researchers have come to the explanation of labeled lines. Labeled lines means each type of receptor whichever are present in our body pain receptor, touch receptor, stretch receptor, vibration receptor they have their distinct pathway which conducts the informations or sensations to the brain.

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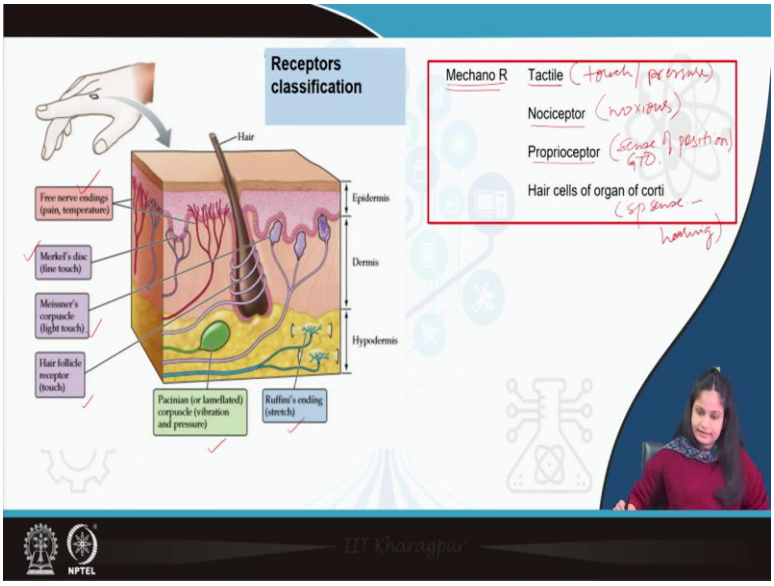

So what are the various types of receptors we get, the classification of receptors are mechanical receptors we have, we have various thermo receptors, we have various chemical receptors, we have polymodal receptors. So mechanical receptors we have tactile receptors, tactile receptors

are mainly for touch and pressure. Then we have nociceptors, nociceptors means the receptors which responds to the noxious stimuli, noxious stimulis mean painful or harmful stimuli.

Then we have proprioceptor, proprioceptor means the receptors which usually responds or tell about the sense of position of our body where is my hand, where is my leg, how is my finger oriented, so these are mainly told by the proprioceptors like golgi tendon organ in our body or joint capsules, these are the proprioceptors.

Then we have hair cells of organ of corti, this is a special sense receptors mainly responsible for hearing. So these are the various types of mechanical receptors, tactile receptors, nociceptors, proprioceptors, and hair cells organ of corti. In the diagram where it has been in the shown in the left side there are various receptors mainly concerning the tactile receptors, the mechanoreceptors, the tactile receptors there is shown, the free nerve endings the Merkel's disc, the Meissner's corpuscles, hair follicles, Pacinian corpuscles, and the Ruffini's end organs. So these are all the receptors which are the tactile receptors.

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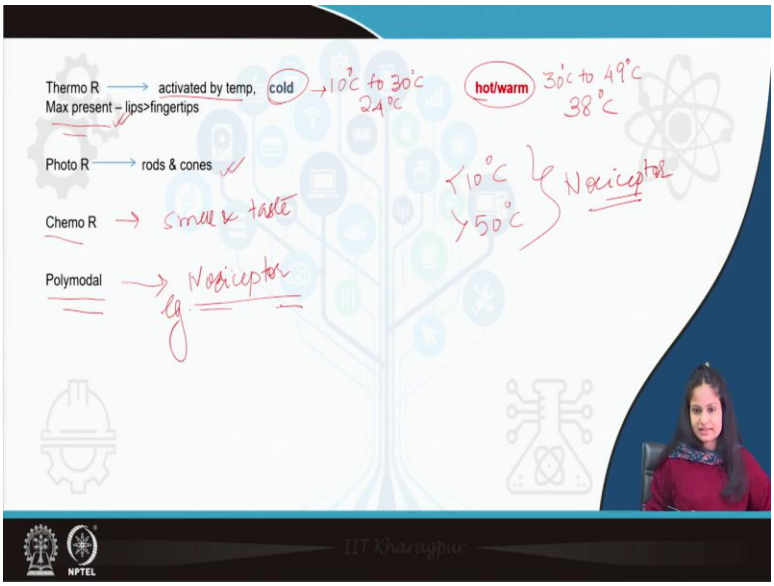

Now thermoreceptors, I told you thermoreceptors means you are feeling hot water hot or cold water cold because of this thermoreceptors. So these are receptors which are activated by temperature. So we have cold receptors we have hot and warm receptors. Usually the cold receptors they usually act in the range of 10 degree centigrade to 30 degree centigrade. And maximum they act at the range of 24 degree centigrade. And hot and warm receptors they

usually act in the range of 30 to 30 degree centigrade to you have 25 to 30 degree centigrade to 49 or less than 50 degree centigrade.

The most stimulus or the most average temperature is 38 degree centigrade to which this receptors act. Now the important question is, what will happen if the temperature is less than 10 degree centigrade or if the temperature is more than 50 degree centigrade, then which receptors will act. Now if the temperature is less than 10 degree centigrade suppose minus 3 degree centigrade or if the temperature is 100 degree centigrade do you think you will like say it is hot or cold obviously will tell it is painful.

So that time, it will be noxious stimuli and this will be acted by the nociceptor. So this will not be at that time taken by the thermoreceptors. Then we have the photoreceptors, before that the thermoreceptors are maximally present on the lips, that is why we when we take hot or cold water we feel the most sensations in our lips, the receptors are present more in the lips compared to the fingertips.

Then we have photoreceptors for our vision, rods and cone cells. Then we have chemo receptors the smell and taste. Then we have polymodal receptors, polymodal receptors are nothing but the nociceptors. The polymodal receptors they act to various the multiple stimuli. That means one receptor is acting 2 thermal sensations, the same receptor is acting 2 touch sensations, vibration the different modalities of sensations are taken by polyodal receptors. So polymodal receptors are usually seen to be attributing to synesthesia. That means various modalities of sensations are attributed at one point of time.

So the most common example of polymodal receptors are nocicepters though I have told the nociceptors in the mechanoreceptors also.

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So with this classification of receptors, it is very important to know about the nociceptors and the tactile receptors because we will be discussing the touch pressure and the pain sensations. So tactile receptors are present more abundantly in our fingertips after fingertips we have in the lips very important locations fingertips, the ductile receptors are present. Now what are the types of tactile receptors? We have Pacinian corpuscles, Meissner's corpuscles, Merkel's disc, Ruffini's ending and also we have free nerve endings, we have free nerve endings.

So Pacinian corpuses all the receptors are very specific to the action or the or the specific to the stimulus. For example Pacinian corpuscles cells the best stimulus is vibration and this vibration is usually of high frequency. They react to 200 Hertz of vibration and these are the largest as you can see from the diagram these are the largest receptor in our body, it is very sensitive receptor in our body present.

Then we have Meissner's corpuscles, Meissner's corpuscles are numerous in abundantly present in our body. And these are mainly present in the non hairy skin, non hairy skin is also known as glabrous skin, so these are present in the non hairy skin or glabrous skin. And the most important stimulus for this Meissner's corpuscle is movement or light touch. It is also responding, it also responds to the vibration but here the vibration will be of low frequency. So light touch is the best stimulus for Meissner's corpuscles.

Then we have Markel’s disc. Now merkel's disc is the receptor which is present this is the only receptor present in the epidermis. That means the all the other receptors are present in the dermis. So the merkel's disc is the receptor which is present in the epidermis and this is, suppose this is the receptors in the present in the epidermal layer and above this there is a dome shepherd structure, that means that there is an dome shepard layer of the skin which occurs like this. So that is why this receptor is also known as Iggo dome receptor. Iggo dome means, ego is the scientist who has discovered this receptor first.

So this is ego dome shepard receptor and Merkel's disc also is very important, because 2 point discrimination. 2 point discrimination is mainly attributed to Markel’s disc. 2 point discrimination means suppose with 2 points or 2 compass, two needle you are touching on this on the surface of my skin your 2 points should be sensed by me as 2 points not 1 point, so this is mainly done by merkel's disk.

The 2 point discrimination, I should be able to discriminate the 2 stimuli as 2 different discrete stimuli not a single stimuli and that is mainly done by the merkel's disc. Because the receptor field is very less in case of Merkel's disc, the receptive field is very less in case of Merkel's disc. Receptive field means if this is a receptor the field where the stimulus will act that is the receptive field, this is very less in case of Merkel's disc.

If this receptor field is large or it overlaps with other receptors, then you will not able to attribute or you will not able to acknowledge the separate stimuli. So Merkel's disc is mainly responsible for fine touch and then you have the Ruffini's endings these are mainly stretch sensitive receptors and the free nerve endings. So this Pacinian corpuscles and Meissner's corpuscles, these 2 receptors are rapidly adapting.

What do you mean by adaptation I will tell, but before that these 2 receptors are mainly rapidly adapting. Whereas all these receptors Merkel's disc, Ruffini's, and organs Ruffini's endings, Merkel's disc and pre nerve endings, these are slow adapting receptors, rapidly adapting and slow adapting.

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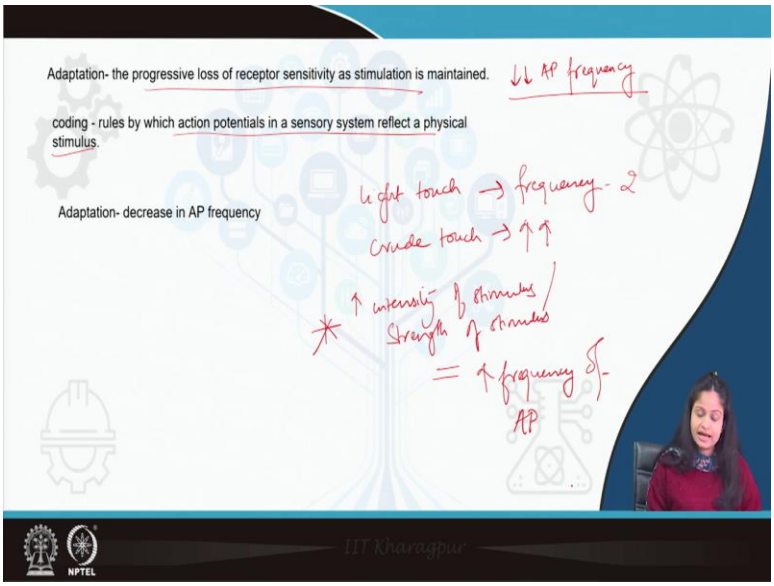

Now what is adaptation? The progressive loss of receptor sensitivity as stimulus is maintained. Suppose if I touch your hand or if I hold your hand, now first time I am holding your hand you are feeling that okay something is there which is holding my hand, but if I keep on holding your hand for a prolonged period, you will ignore it, you will not feel that same touch for a long period. So why that happens, because of adaptation, because of the decreased in the action potential frequency, because of the decrease in the action potential frequency.

The progressive loss of receptor sensitivity as stimulation is maintained when you give supra threshold stimulus, so the action potential frequency gets decreased. Now coding is the rules by which action potentials in a sensory system reflect us physical stimulus. What happens when our brain is not able to, our brain will not be able to telling whether you are touching lightly or you are giving a crude touch, the brain only knows action potential.

How you are touching the brain will not be able to tell. But ultimately you know that whether it is a light touch or a crude touch, how it will know, it will know from the frequency of the action potential. For example, if you give light touch, the frequency whatever will be the frequency suppose the action potential frequency is around 2. And if you give crude touch the action potential frequency will be increased, there will be spontaneous firing of the neurons.

The action potential frequency means the firing of the neurons, how many times the neurons will be fired that will be more as you increase the intensity of the stimulus that means the strength of

the stimulus is coded by increase in the frequency of action potential not the amplitude. Because action potential follows all or non-law, when I am giving more amount of stimulus or the strength of the stimulus is more, that does not means the amplitude or the voltage of the action potential will increase, no because action potential follows all or none law.

So the intensity of the stimulus is very important which depends or codes based on the increased frequency of the action potential and adaptation there is decrease in the action potential frequency.

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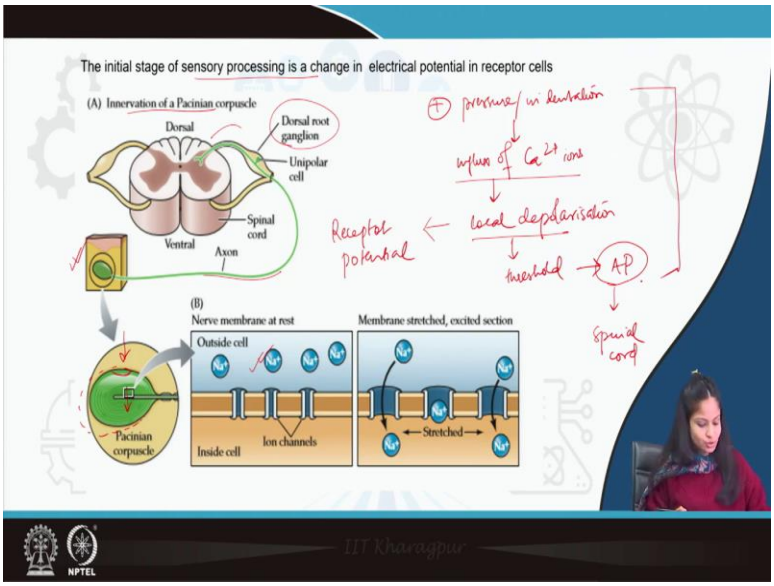

So what happens, we will see how the signal transduction or the sensory processing occurs. Now it has been seen in a Pacinian corpuscles, you can see the Pacinian corpuscle, suppose the receptor is present, this is the receptors present on the skin, the Pacinian corpuscles detects the vibration. So the pacinian corpuscle you can see this Axon type a fiber is taking the sensation via dorsal root ganglion to the spinal cord.

Now how it takes the sensory information. So this is the pacinian corpuscle, the pacinian corpuscle in a larger form. It is shown in the figure, there is a neuron the, there are various nodes of ranvier present the first node of ranvier will be always inside the receptor. So whenever I press the receptor suppose I am giving touch or suppose I am pressing the, I am touching the skin as soon as I touch the skin, there will be touching indirectly or pressing of the receptor also.

So whenever there will be pressing of the receptor there will be indentation which will occur because of this pressing on the Pacinian corpuscle, because of this indentation what will happen there will be influx of certain cations mainly the calcium channels. So because of press pressure or indentation there will be influx of calcium ions. This calcium ions or the they usually enter with the help of stress or the mechanosensitive channels.

So when there will be entry of calcium channels or calcium ions, what will happen there will be local depolarization. So this local depolarization if it reaches to the threshold level then this will give rise to action potential and this will be carried forward to spinal cord. So action potential is getting enhanced that means there will be more influx of sodium ions we know nodes of ranvier are bearing or having large amount of sodium ions.

So whenever there will be influx of calcium ions, there will be local depolarization. This local depolarization is nothing but known as receptor or generator potential. There is formation of receptor potential or generator potential and if this receptor potential crosses the threshold level there will be more influx of sodium ions and finally that will result in action potential, then that way the sensor information is conducted to the spinal cord.

Now what happens in case of adaptation, if this indentation or if this pressing is given for a longer period, what will happen, this pacinian corpuscle this will extend or this will adjust its size. It is like a balloon, it will you are pressing and it is adjusting its size. Now when it is adjusting its size there will be no tension. So when there will be no tension there will be no stress sensitive calcium channels opening. Whenever there will be no stress sensitive calcium channels opening this whole procedure will be abolished.

So there will be no action potential firing, in this way there is no sensory transduction occurring and we do not get that feel or touch anymore and the receptor gets adapted. In this way there is rapidly adaptation occurs in a receptor. And in this way there are certain receptors which adapts slowly. So this is all about your adaptation.

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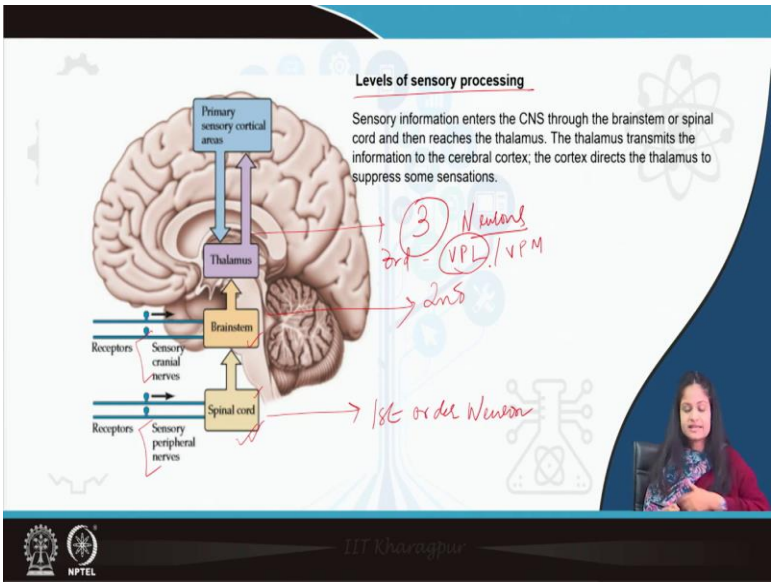

Now how the sensory processing occurs? The sensory processing occurs at various levels. We have to remember the 3 neurons or the 3 level of neurons. The receptors are taking the information, the receptors will taking, the take the information with the help of peripheral nerves. In case of sensory peripheral nerves and from head and neck there are cranial, cranial nerves. So where it will take the information to the spinal cord and the brain stem.

So spinal cord is the first order neuron, here we get the first order neuron. Then we get at the level of brain stem mainly at the level of medulla, the second order neuron. And then at the level of thalamus we get the third order neuron. So 3 order of neurons we get where this processing occurs from the spinal cord to the brain stem at the level of medulla, then thalamus, from thalamus to the sensory cortex which portion of the thalamus mainly the ventro posterolateral, ventro posteromedial also mainly the wounded ventro postro, vpl nucleus of the thalamus is important. So at all level sensory processing occurs and information is taken to the cortex.

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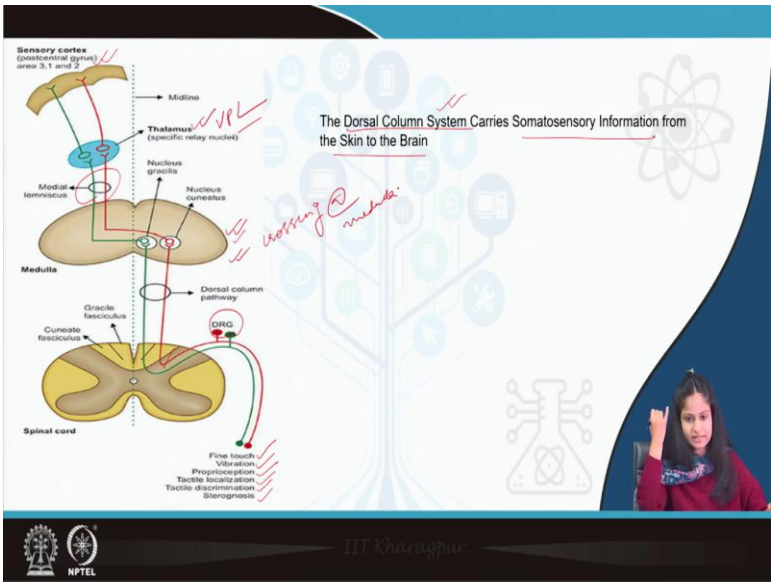

Now how the touch sensation is taken, mainly the dorsal column system of our body they carry various somatosensory information from the skin to the brain. From the skin, what are the sensations, fine touch. Vibration. Proprioception, tactile localization where you are touching, tactile discrimination and stereognosis. Stereognosis means if I ask you to close your eyes and tell to hold the pen and ask you what you are holding you will be able to say, okay this is a pen I am holding. If you are not able to tell then that is asteriognosis.

So fine touch, vibration, proprioception, tactile localization, tactile discrimination stereognosis all these sensations are taken by dorsal column pathway, this is the ascendant tract. Now you can see dorsal column pathway, these are taking sensations both from the upper limb and the lower limb to the dorsal root ganglion. Dorsal root ganglion from here, it is synapsing at the level of medulla. First it synapse at the level of spinal cord, then at the level of medulla, then from here you can see with the help of medial lemniscus, it moves to the relay center that is thalamus, here the nucleus is vpl and from here it is sensory cortex.

Now dorsal root in this, at the level of spinal cord this dorsal column pathway will not be crossing but it usually crosses at the level of medulla. So the crossing occurs at the level of medulla that means the sensation whichever they are taking this is from the opposite side of the body, the left side sensation is taken to the right side, right side of our brain. So this is the dorsal column pathway.

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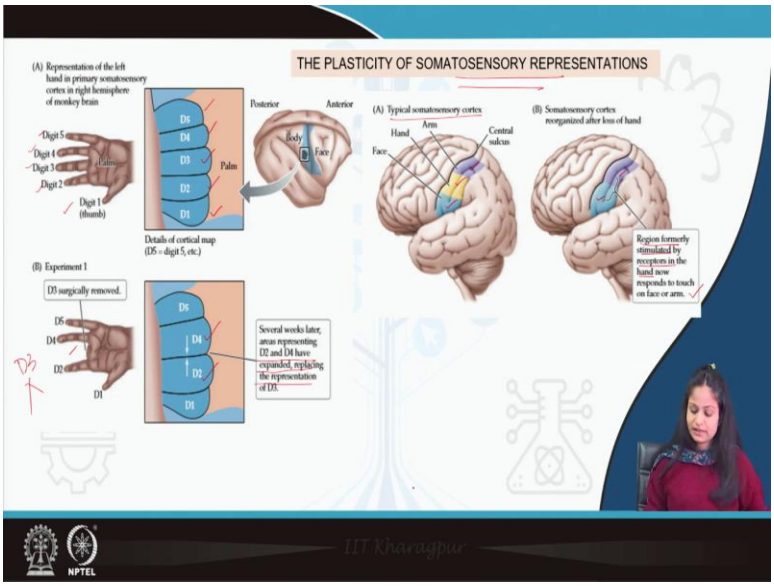

Now the plasticity of somatosensory representations. Now how the somatosensory representation is present in our brain, how the hands and limbs are present in our face and mouth are present, this I had already discussed in the cerebral cortex lecture as in the name of homunculus somatotopic organization that is homunculus. Now what happens, suppose this one, this you can see the fingers digit 1, 2, 3, 4, 5, 5 fingers of our hand, these are represented in our brain. You can see the cortical map is there in the brain D2, D1 D2, D3, D4, D5.

Now experimentation has been done suppose if there if I remove surgically one finger, you can see I have removed the D3, the middle finger is removed. So what will happen after some time the whether there will be any vacant portion in our brain? No, what will happen D3 is removed. So D4, and D2 will expand and replace the position of D3. So there will be expansion of D2 and D4, and that will be replaced, and that will replace and represent actually the D3. So if any sensations or if any stimulation occurs at the level of this region, I have removed my finger, okay that does not mean that I will not end get any sensation at the level of my cortex.

So that is what happens whenever this is the normal somatosensory cortex of a person the where the person is having is hand but if suppose the hand is removed I mean there is an accident the hand is amputed. So now the person is not having hand, this is the arm, this is the hand, this is the face. So you can see after some time with prolonged duration the face and the arm portion in a in the cortex has expanded and taken position the region formally stimulated by the receptors in

the hand, now responds to touch on face or arm. So in this way plasticity or regeneration or reactivity of the somatosensory system occurs, whenever there is a deletion of any organ.

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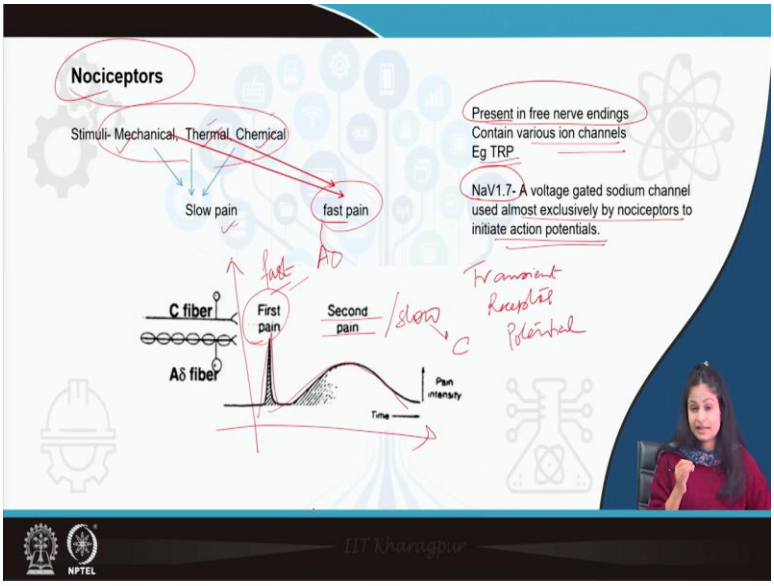

Now we will come to the nociceptors, nociceptors mean the painful receptors. So various nose receptors are present in our body mechanical, thermal, or chemical all this give rise to pain. The free nerve endings in our body are the nauseous other receptors for the pain sensation mainly because they contain certain ion channels which usually respond to pain and temperature. So this iron channels are nothing but transient receptor potential channel, transient receptor potential.

So these are transient receptor potential channels and also it has been discovered by the various scientists recently that this voltage-gated sodium channel NaV 1.7, this is usually exclusively seen to be activated during the nociceptor stimulations and they are mainly the cause of action potential. So various types of this nociceptors, they usually result either fast pain or slow pain what will happen, suppose I get stimulation there is a pain sensation you are getting from the I, I pinch you very badly and you get a pen sensation immediately, the pain sensation which you will get that is first pain or fast pain, both first or fast. And after that you will get certain nagging type of pain, that is second pin or slow pain.

So you can see if this is the in pain and intensity curve. So the fast pain is very rapid and immediate and the slow pain is a dragging or the nagging type of pain. Now both are usually carried by different fibers. The fast pain is mainly carried by a delta fibers, the slow pain is

mainly carried by the c fibers. Now we will see how the fibers carry this fast pain and the slow pain. Now mechanical thermal and chemical all the 3 nociceptors are usually giving rise to slow pain but typically mechanical and thermal will give rise to fast pain.

So if I ask you question if there is an acid burn acid is a chemical then it will give rise to which type of pain, it will give rise to slow pain. Now immediately if you throw acid on someone immediately there will not be any pain, but later on there will be intense nagging pain.

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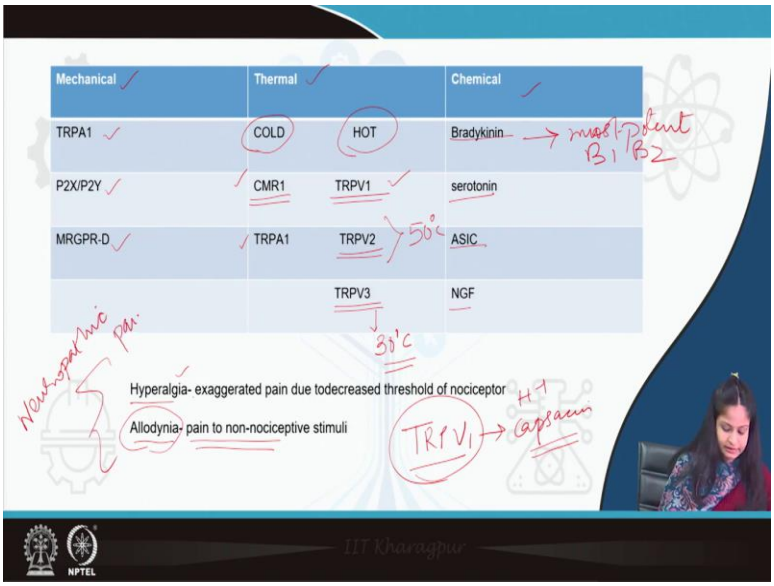

So what are the receptors we see, there are various nociceptors mechanical, thermal, and chemical. Mechanical we have TRPA1 P2X P2Y mass related G protein coupled receptor. Thermal receptors we have both for cold and hot, we have CMRI, CMRI receptor is cool menthol receptors when we put mint or menthol we feel a cool sensation. So that is mainly because of this receptor CMR1 and TRPA1, hot receptors are mainly the TRP V stands for vanilloid, vanilloid receptors. TRP V1 receptors, TRP V2 receptors and TRP V3 receptors.

Now TRP V1, V2, V3 this all receptors they act on different temperatures, V3 receptors mainly act at 30 degree centigrades mostly at the body temperature and V2 receptors mainly act for more than 50 to 60 degree centigrade. Now chemicals bradykinin, serotonin, acid sense, acid sensing ion channels and various nerve growth factors, another important the hot receptors TRPV1, they also act or react to H plus ion and capscin. Capsaicin means the sensation which

we get when we take chili, chili powder or chili, when we eat we get a very burning heat sensation that is mainly because of this TRP V1 receptor.

The most potent pain receptor is the bradycinine most potent pain receptor, it acts on B1 and B2 that is the bradykinin. We have 2 terms hyperalgia and allodynia. Hyperalgia means there is a nociceptor but there is an exaggerated response to that nociceptors and allodynia means there is not we do not have a noxious stimuli we have a plane stimuli but still we are having pain or reporting pain to that non nociceptic stimuli that is alodonia. So these are all features of neuropathic pain or chronic pain, neurological disorder we see neuropathic pain.

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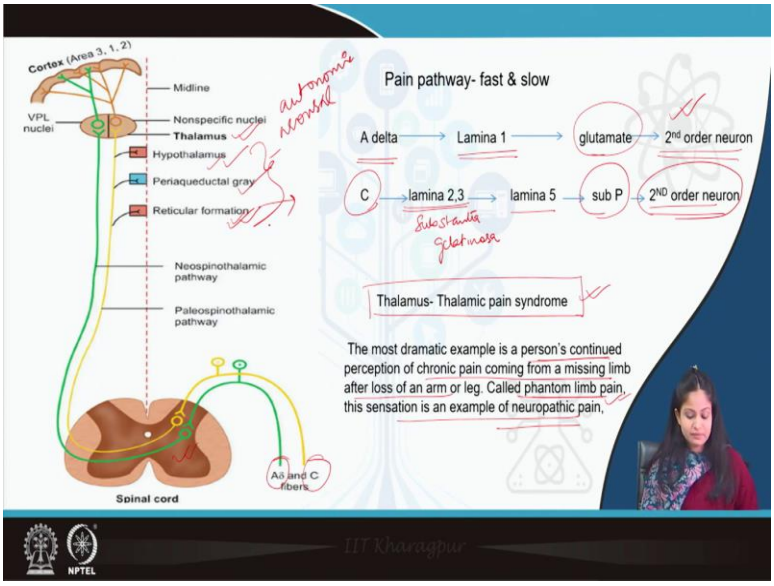

This features we see, now how the pain pathway is different between fast pathway and slow pathway will see, mainly the spinothalmic tracts the interlateral spinothalmic tracks, they conduct the pain and temperature. So the A delta fibers if you see this A delta fiber is carrying the fast pain and C fibers are carrying the slow pain. And at the level of spinal cord only they are crossing to the other region of the other cortex I mean other side of the body. So A delta fibers they usually terminate at the lamina one of the spinal cord level and they secrete glutamate.

This glutamate will stimulate the second order neurons and the second order neurons will further relay on the thalamus. The C fibers or the slow fibers, this will rely on this lamina 2 or 3 also known as SG that is substantia gelatinosa, this will relay on lamina 5 altogether and secret

substance P not they will they also secrete glutamate but the main substance of pain over here in case of slow pain is substance P and they will stimulate the second order neuron.

The most important thing is in the first pain pathway thalamus is the main center where the pain is related. So that is why if thalamus is destroyed or thalamus is malfunctioning because of any stroke or hemorrhage or the VPL nucleus is getting disturb because of the Hemorrhage then there will be intractable spontaneous pain, I had already discussed this in the thalamus lecture. Because of and it is not relieved by analgesics, because of this thalamic pain syndrome.

The most dramatic example in in a person's when they tell about chronic pain is a missing limb after loss of an arm or a leg that is known as phantom limb pain, this sensation is an example of neuropathic pain. The phantom limb the person is not having the limb but still there will be stimulation of the nerve fibers and that will cause the sensation as if the person is having pain from that amputed or missing limb, so that is phantom limb.

So phantom is like which is not there but still the feeling or fantasy is there. Now the C fibers will relay on the second order neuron and this second order neuron will get relayed on the hypothalamus periaqueductal gray region and reticular formation. Because of this periaqueductal gray region and reticular formation there will be autonomic arusal, there will be sweating, there will be increased heart rate, there will be there can be increased BP. And reticular formation keeps the person awake.

Whenever there is pain you will see the person is awake they are not able to sleep at night because of this slow fibers which will affect the peri aqueductal and the reticular formations.

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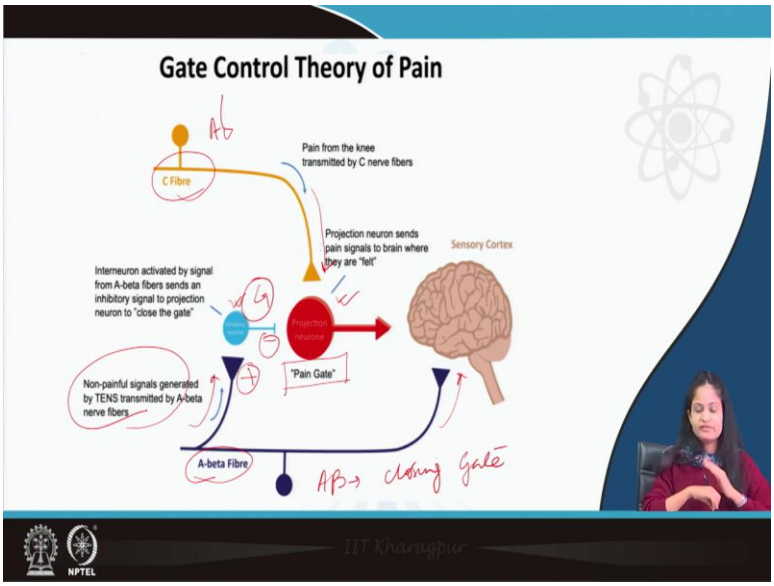

Now in our brain in our central nervous system, there is always 2 pathway that is one at the spinal level and one at the supraspinal level which causes deactivation of the pain or inhibits the pain, how. Now this is the C fibers or A delta fiber which is carrying pain. This is the projection neuron at the level of spinal cord. There is an inhibitory neuron or G neuron which secretes inhibitory neurotransmitter.

Suppose A beta fiber which is usually stimulated by touch or rubbing that also sends its pathway to the spinal cord and the brain. So if we touch or we do rubbing this a beta fiber, fiber gets stimulated it sends a interneuron to this G neuron. And this G neuron will get stimulated that it will secrete further inhibitory neurons and further inhibit or close this pain gate. So A beta fiber is actually closing the gate.

So this is gate control theory of pain, this is mainly seen when we do acupuncture or if we apply balm whenever there is a palm, we pain we are applying balm, so we feel less pain because of this gate control theory of pain with the help of A beta fiber.

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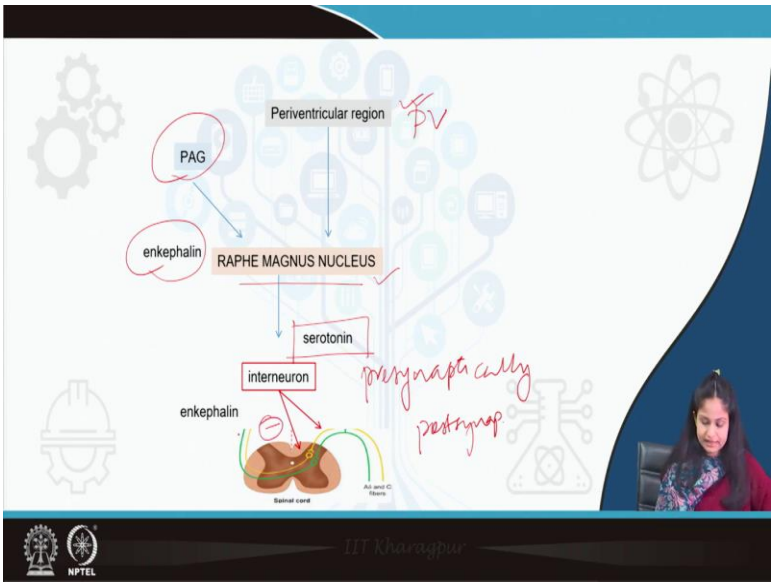

And lastly the supraspinal control of pain which occurs mainly with the help of periventricular region, PV region and periaqueductal region of gray region. Now this will secrete enkephalin are the endogenous opioids. So this will stimulate the rafhe magnus nucleus, the rafhe magnus nucleus will secrete neurons which will secrete serotonin. This serotonin will act pre-synaptically as well as postsynaptically and inhibit the pain sensation.

So in this way, this is the supraspinal control of pain where serotonin is inhibiting pre-synaptically as well as postsynaptically, the neuron at the spinal cord level.

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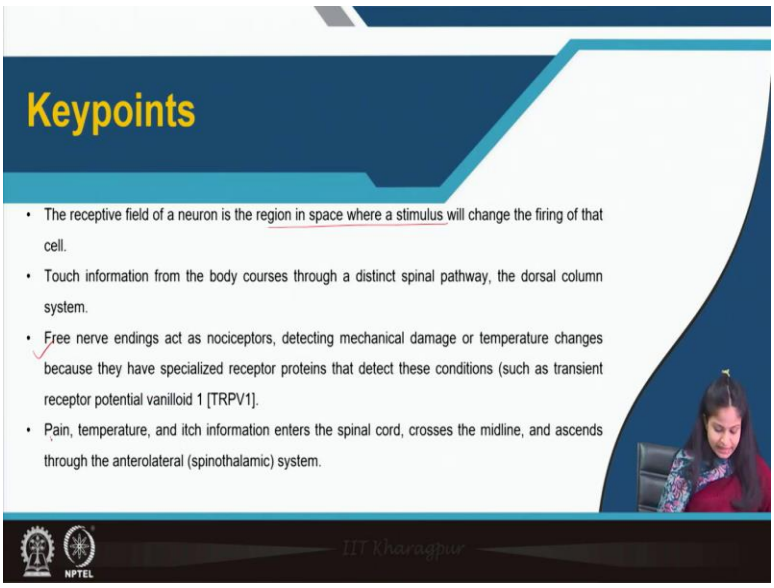

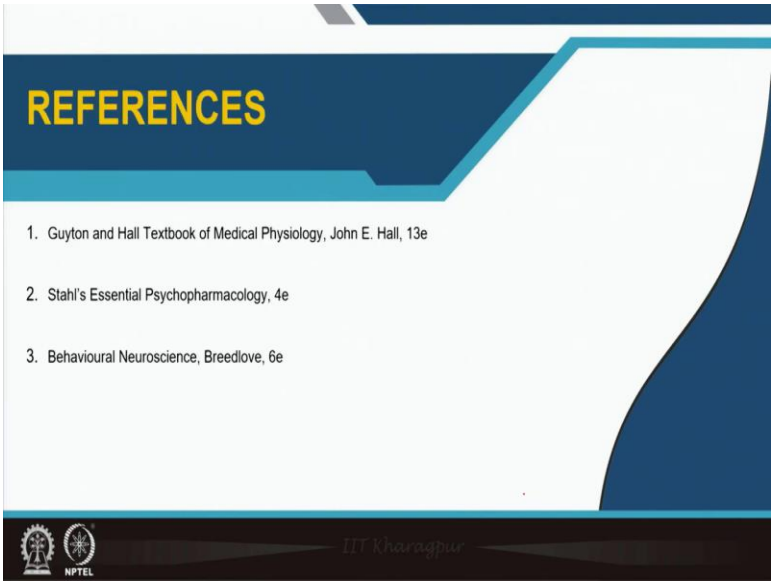

So the key points you have to remember is the receptive field is the region in space where a stimulus will change the firing. Touch sensation is from a distinct pathway that is dorsal column pathway. The free nerve endings they act as the nociceptors and they bear specialized receptor proteins, mainly the transient receptor potential vanilloid receptors. And pain, temperature, and itch, the itching sensation is also borne by the spinothalmic pathway. This much you have to remember in the physiology of sensations. Thank you.