Cognition and its Computation
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Lecture - 21
Sensory Circuits: Somatosensory

Welcome. So, we have been discussing Sensory Circuits. We have understood or rather we have discussed aspects of how receptive fields in the visual and auditory system are organized and how the hierarchy of processing occurs in the visual and auditory system. So, for we will later on in the course, we will be talking primarily about vision and audition.

However, for the sake of completeness we will also talk about at least introduce you to the ideas of the other sensory systems that is the somatosensory system and also the chemicals sensors which is the olfactory and gustatory system.

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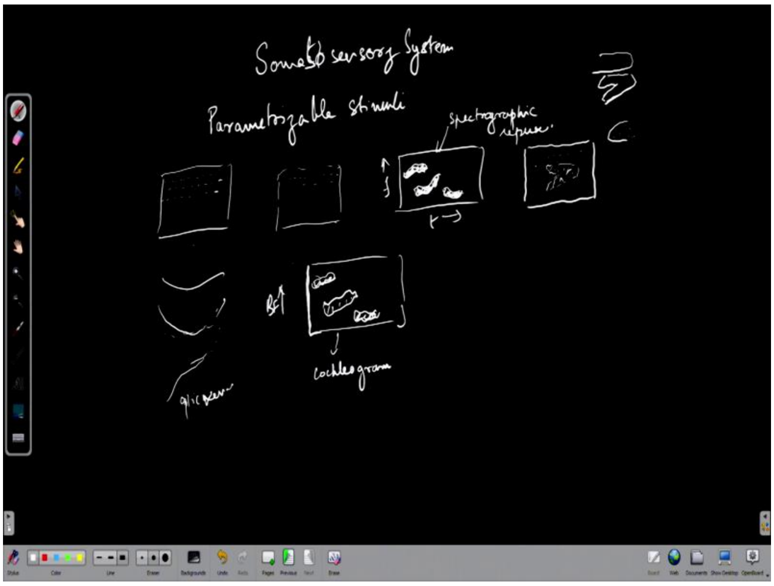

So, in the somatosensory system which is; so, let us let us remind ourself that the somatosensory system is also one of the systems that has to do with parameterizable stimuli. And in this case the stimuli can be put into a space of with order the basic parameters of the stimuli are in ordered space. For example, the amount of pressure, frequency of vibration or stretch or pull on a skin the force, the velocity of movement of a muscle, the angle of a joint.

The all these are different forms of somatosensory stimuli or aspects of the somatosensory physical world that are captured by the somatosensory system. The peripheral somatosensory system and conveyed on into the central nervous system. So, the following the basic ideas of breaking down the stimulus into very small entities. For example, in the visual system in the retina we had said that the visual space is broken down into very small spots or almost like pixels in a computer screen by the and is picked up by the photoreceptors

And the retinotopic organization of the visual pathway shows that if we in. So, this is forming an image on the retina. So, if this is the eye, we are forming an image on the retina and the retinal ganglion cells, which form the optic nerve. That carries information to the lateral geniculate nucleus. If we organize the optic nerve by their location or by the location that they are sensitive to and visualize their activity on a screen by positioning their activity as pixels on there, the nerve essentially contains an image of what we are observing.

Similarly, in the auditory system as we have said that the auditory nerve fibers carry information about the different frequencies or intensity in different frequencies in the auditory nerve fiber activity or their action potential. So, similarly if from the auditory system, if I take the sound, we know that the sound can be represented as a spectrogram.

That is in terms of how energy is distributed at different frequencies around over time. So, this axis is frequency this axis is time and let us say that the regions that I have shaded white have high energy and the other regions have lower energy. And generally sound has different frequencies that that are present in the sound at different times in different amounts. So, this is what we call the spectrographic representation and similarly if I take the activity of auditory nerve fibers with the different best frequencies on one axis and we plot their activity we in a proper time scale.

We would actually be able to see the similar sort of image of the sound which is the spectrogram here. That will be present in the cochlear auditory nerve fibers. So, that will that is it is all called what is called a cochleogram or that is the activity of the fibers contain an image of the sound or how the sound frequencies are changing with time or how the energy in different frequencies are changing over time.

Exactly in the same way the peripheral somatosensory system, if we could put all the nerves nerve fibers collecting information of a particular aspect let us say only pressure on the skin and look at the activity or and plot the activity high activity and low activity across a screen that is somatotopically organized. So, let us say I am with my fingertip I am touching a particular shape let us say a braille and it is like a v that I am pressing and understanding.

So, if it is a v I am pressing and understanding it is a v. So, that now if I take the nerve endings nerves fibers from there and their activity is plotted somatotopically, that is all the fibers from my finger from the tip of my finger all the nerve fibers that carry the activity going forward, I can actually observe the activity as this v. So, essentially an image of whatever the pressure sensors are collecting is conveyed onto the central nervous system.

So, the somatosensory system in that sense is also providing similar kind of information from the periphery into the central nervous system. It is only a matter of how we parameterize or visualize the stimulus. In the visual system it is easy to visualize it because we are ourselves looking at it. In the auditory system we have to make some transformation of the stimulus to get a picture of what the stimulus is and that is what is represented in the peripheral fibers.

Similarly, in the somatosensory system again it is the fibers activity that is conveying the image of the stimulus. If you will, that is in this case the pressure that I am feeling about the v only the v region and not the, so not the other regions. And that that is implemented in the activity of the fibers and if we could visualize that activity somatotypically organized we would see exactly what we are feeling with the pressure.

So, I have just given this example to show you the similarity between all the three modalities and it is in the central nervous system. It is about computing this features; what features we are interested in and making a conclusion about what we are perceiving? So, in this in the somatosensory system there are many physical parameters that are involved I have talked about only the pressure case.

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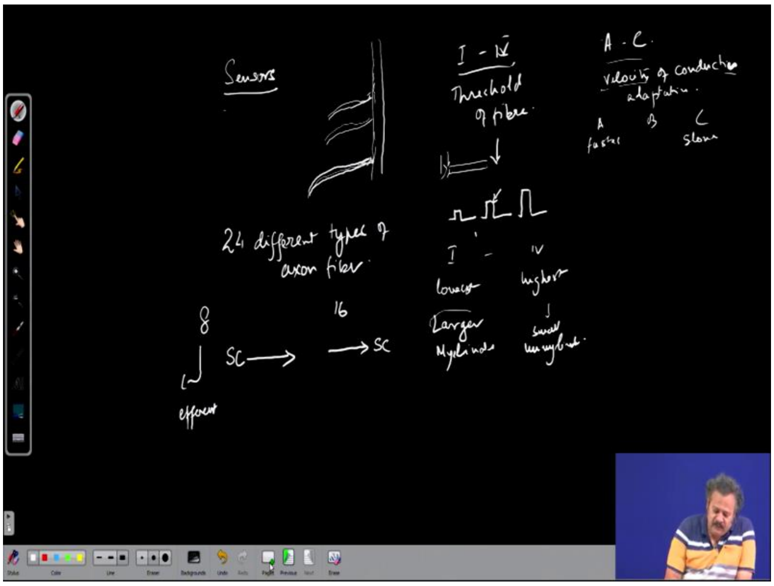

So, just like in the auditory and visual system there are there is a first stage where there are sensors in the periphery. Here, also there are many different kinds of sensors that are present in the periphery. The pathway is organized in the sense that the different nerves carrying all this information from different parts of the skin get finally, reach the spinal cord, which takes the information up into the brain.

So, the fibers carry information into the central nervous system. The first stage in the central nervous system is within the spinal cord. And then it ascends further with other regions of the body providing input into the spinal cord, which goes further up there are two parallel systems that go up we will talk about that. So, now, in terms of looking at what kind of information comes in and the how the nerves are organized. Basically they have 24 different types of fibers present in the peripheral somatic system.

Axon fibers of these 24, 8 types are efferent fibers. In the sense that these fibers provide or go from the spinal cord to the periphery, providing information to the periphery or carrying information to the periphery. That is the different part and the other 16 are the type that carry information into the spinal cord through the peripheral somatic system. So, given all these different types these types are based on a variety of factors and they can be grouped in certain ways.

There are two different ways they are usually grouped. One is type I through IV this is based on thresholds of the fibers to electrical stimulation. Threshold of fiber to electrical stimulation; meaning that if we stimulate in the peripheral nervous system in the somatosensory system with electrical currents as we have talked about in our measurements lectures. If we stimulate electrically, then if we start with a small current pulse and gradually increase the current pulse, height that is making the electrical stimulation stronger and stronger. There may be a time point where the and now we are recording from the fibers.

There is a time when the amplitude is sufficient to cause activity in the fibers or firing activity in the fibers, action potentials in the fibers. Then that particular amplitude is the threshold. So, the types of fibers based on this threshold are I to IV meaning I has the lowest threshold and IV has the highest threshold. Generally, I is the larger of the and larger and myelinated fibers. And the highest thresholds are small unmyelinated fibers.

Another way of grouping these fibers that has been there is basically A through C and that is based on the velocity of conduction. And also, adaptation how adaptation these factors in mainly the velocity of conduction in those fibers and A is the fastest of them and it generally coincides with group one fibers, but then there are subgroups within A that go into different numbered fibers.

So, they are not exactly corresponding. So, C is the slowest; obviously, based on the fibers. So, these are the general types in which the peripheral somatic system or the fibers are organized.

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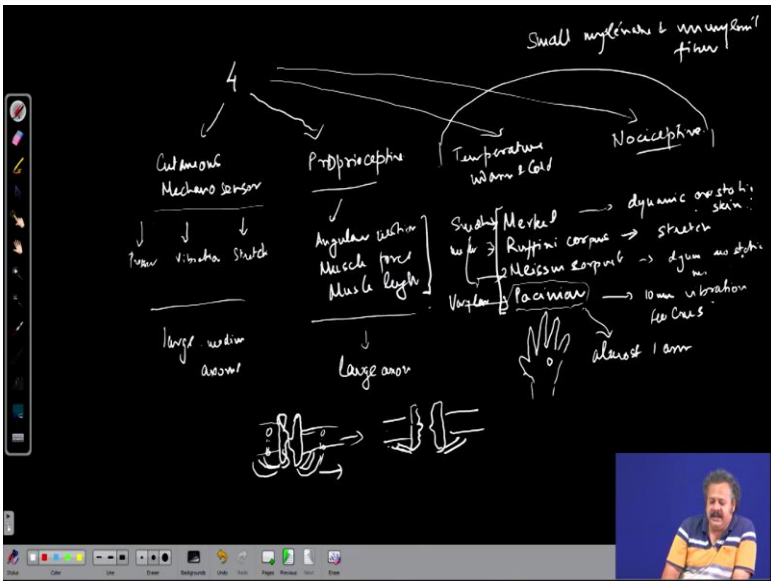

In terms of the information that is carried forward by the afferent somatosensory somatic system fibers is there are mainly four types of information that is carried forward and that is first is Cutaneous or that comes from the skin cutaneous, Mechano sensitive fibers that is the forms of information that is acquired from the skin and has to do with mechanical sensation.

In this comes the different cases of pressure or force, vibration, stretch etcetera. Then there is the proprioceptive proprioceptive information that comes in. And that has to do with angular motion information, muscle force information, muscle velocity, muscle length these kind of information that actually provides us information from inside our body to give us an understanding of where my hand is, where my fingers are with respect to an object.

So, when I am going to pick up something. I need to have information about how my this angle this elbow angle has to be changed. And so, I require my current information about the elbow angle. And so, I tell my motor system to move it move the muscles or stretch the or contract the muscles accordingly. So, we have not talked about the motor system. We will talk about in a later lecture.

So, these this is what is called proprioceptive information. And is important in all our in understanding all our internal positions of and the state of the muscles that are controlling various parts or bones of the body. And then there are two other forms of information that come in. One has to do with temperature. That is warm and cold information and the other is the nociceptive information, that is that has to do with the noxious stimuli. That is a prick or an itch and so on.

So, these are carried forward by specifically by the small myelinated and unmyelinated fibers. This is primarily by the large axons these are also large to medium axons. So, this four forms of information is collected in through the spinal cord to go further up into the brain. So, the way these sensors work primarily the cutaneous and proprioceptive is totally based on mechanical sensing.

And the basic principle is basically based on an opening of an ion channel. Let us say an ion channel that has a structure like this. Which is closed and they have some cytoskeletal proteins. That are attached to the inside here this is the cell membrane as we know the lipid bilayer and this is an ion channel that allows ions to flow in or out of the receptor neuron or even at the nerve ending.

So, a contraction based on the mechanical force that is received on the skin, that they cause the ion channel to open. So, they physically stretch or move the segments of the ion channel. So, these cytoskeleton proteins are basically pulling or contracting and opening the ion channel. So, we can imagine that based on the orientation of the receptor and position of the receptor on the skin or under the skin we can get information about pressure depending on how these are oriented.

We can get information about stretch we can get information about vibrations. So, the primary types of fibers that provide information in the cutaneous mechanosensors or the receptors are the Merkel receptors, the Ruffini corpuscles, the Meissner corpuscles and Pacinian corpuscles. These are the main mechanosensitive receptors that are present the Merkel receptors get information about dynamic as well as static and static skin deformations.

And, they are carried forward by slowly adapting fibers. The Ruffini corpuscles also carry information about the mainly about stretch, information from the skin. The Meissner corpuscle again carries information about dynamic and static stimuli. But they are carried forward by rapidly adapting stimuli and so they are much more sensitive to motion. The Pacinian corpuscles they are the most sensitive and are large sort of receptors. And are kept and they are deeper in the epidermis.

And they can sense up to 10 nanometers change through vibrations, even a centimeter away mu few centimeters away, in fact, few centimeters away. So, you can imagine how sensitive these Pacinian corpuscles are. So, and these fibers have very large receptive fields. Merkel sensors or Merkel receptors are extremely small receptive fields. So, are and Ruffini and the Meissner corpuscles are also have extremely small receptive fields.

So, these have small receptive fields in terms of the size; these have medium receptive fields to large receptive field these are extremely large. So, for example, what I mean by small? If we have the this is our palm let us say with 5 fingers and a thumb, this sort of small a very tiny region in the palm can be the size of a receptive field of a fiber that carries information from a Merkel receptor.

And, a Pacinian corpuscle on the other hand the other extreme is that almost full to half to full arm itself can be the overall receptive field of a Pacinian corpuscle almost full 1 arm. So, the entire arm, the vibrations of a small amount can be detected by 1 Pacinian corpuscle. So, this is the cutaneous mechanosensors. The proprioceptive sensors are range from again in this type of from Pacinian corpuscles to Ruffini corpuscles also.

And, there are other receptors that is they are embedded in the like the Golgi tendon receptors that is embedded in the tendon to a muscle and carries information about length or force on a muscle. Then, there are angle joint receptors or angular receptors. And, so, they are active only at certain angles of the only at certain angular positions of a joint.

And, then there are 2 further receptors that carry that provide information about the relative positions of 2 muscles through based on the joint. And, the warm and cold temperature receptors, there are 4 types, two that are more sensitive to static changes.

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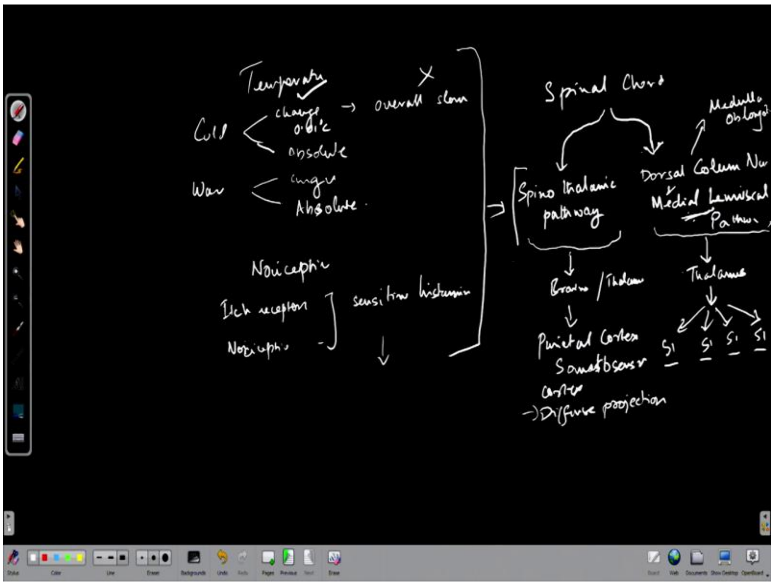

So, in terms of the temperature, in the cold and the warm there are 2 types; one that is sensitive to changes and not so sensitive to overall slow changes. Only very small immediate changes very fast changes, even up to 0.01 degree Centigrade drop can be can be sensed by nerve endings, with specific types of proteins that are present and that are sensitive to temperature changes.

And, the amount of depolarization that such a change can provide is almost equal to a 10 degree Centigrade change over a very long time. Similarly, the warm receptors are also of generally 2 types; that is one that is sensitive to change and or fast changes and one that is more of an absolute or slow change measurement. And, there I mean we are talking very broadly there are many types of sensors that are present.

I mean it is the most complicated set of receptors that are put together in order to convey all the somatosensory information. Similarly, they are for the nociceptive stimuli, there are each receptors that and nociception. So, like these are one of the ways one of the things is being sensitive to presence of histamine. And, there are whole set of receptors for different kinds of nociceptive stimuli or painful stimuli and so on.

So, refer I mean it is not possible to go over all the classes and the ways of transduction of all of them in our this small lecture. But we wanted to provide you the idea of how the somatosensory system is organized. And, then later on towards at the very end when we discuss current research topics, we will refer to some of these. Now, after entry into the central nervous system through the spinal cord, there are 2 different pathways, that carry information up to the thalamus.

One is the spinothalamic system or spinothalamic pathway and the other is the dorsal column nucleus dorsal column nucleus and medial lemniscal pathway. So, this pathway carries information from the spinal cord at the different levels carrying information from the leg, trunk and arms and then face and goes onto a brain stem and the specific regions of the thalamus. And the information they carry is about these temperature and nociceptive stimuli.

And, this is a parallel path that goes up from the thalamus into the parietal cortex; one into the parietal cortex. So, there are basically 4 regions; 3 in the thalamus and 1 in the brainstem that directly project there. So, parietal cortex, somatosensory cortex and a diffuse projection from a particular nucleus throughout the cortex; I mean, all the different regions possibly for multi-sensory integration diffuse projection for many different regions in the cortex.

The on the other hand the dorsal column nucleus and medial laminiscal pathway, that carries information finally, from the so, it goes through the dorsal column nucleus in the medulla oblongata. And, then goes up to the medial laminiscal. So, I mean this is in the medulla oblongata, a particular structure. Then, the projections carry on into the medial laminiscus.

And in the medial laminiscus, the contralateral side information I mean unilateral side information crosses over to the contralateral side. And then it projects to the thalamus there are different nuclei in the thalamus that are involved here. And, then there is a projection to 4 different regions of the primary somatosensory cortex S 1. And, these 4 regions are distinct and process distinct types of information.

But, all this pathway has to do with our form and texture perception and involved in the proprioceptive information processing. So, from S 1 then it goes on to secondary regions and there is further integration of information from motor cortex regions and so on. So, this is was more of a description of the somatosensory pathway and we have not really talked about coding and the specific forms of activity of neurons that convey different aspects of the stimuli.

But, we have shown that it is organized in a particular way, which becomes important later on when we talk about some of some questions about somatosensory perception. So, with this we will close our discussions on somatosensory processing or circuits and in the next lecture we will take up the chemical sensors that is the olfactory system and the gustatory system.

Thank you.