Introduction to Brain & Behavior
Professor Ark Verma
Department of Humanities and Social Sciences
Indian Institute of Technology, Kanpur
Lecture 13 - Neuroscience of Sensation and Perception

Hello and welcome to the course, Introduction to Brain and Behavior. I am Dr. Ark Verma from IIT, Kanpur. As you know I work at the Department of Humanities and Social Sciences and also the Interdisciplinary Program for Cognitive Sciences. This is the third week of the course and we are talking about neuroscience of sensation and perception. Today, we will talk about a particular sense called somatosensation.

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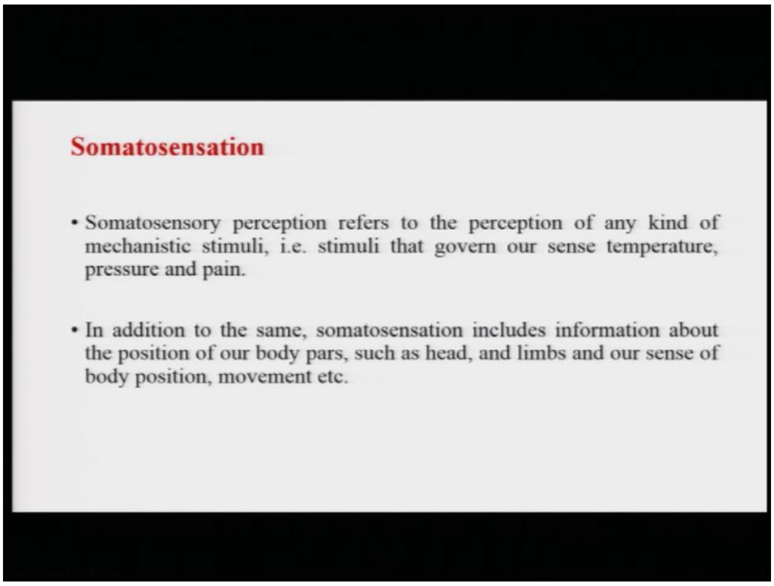

Now, somatosensory perception refers to the perception of any kind of mechanistic stimuli, any kind of stimuli that are involved in terms of giving us pressure sensations. Say for example, you touch something, you hold something, you grab something, or something or sensations that are informative of aspects like temperature, pressure and pain. So, somatosensation in that sense is a fairly important area. It is a fairly important aspect of our sensory abilities. One, that helps us navigate the environment, one that helps us deal with different kinds of objects in the environment and also that has a lot to do with our safety and survival in this environment.

In addition to providing information about the senses of temperature, pressure and pain, somatosensation also includes information about our body position, the position of our body parts, our head movements, or the position and movement of our limbs, sense of body position, et cetera. In that sense, somatosensation is something that helps us stay upright. It helps us walk around, it helps us walk around, run, play sports, perform all kinds of activities that involve manipulation of the body in the environment.

So, if you kind of -- if you think of this, somatosensation is probably one of the most important sensory capabilities that allow us to navigate, go around in the environment and interact with the environment.

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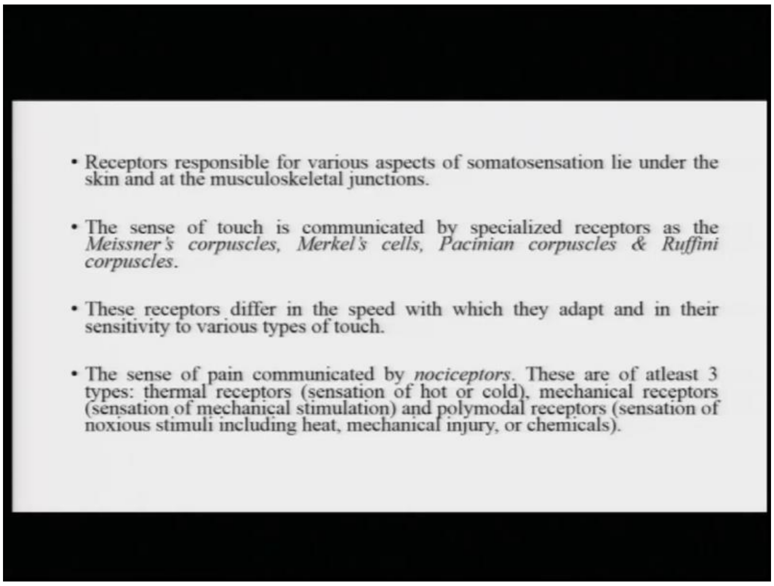

Now, where are the receptors that are responsible for somatosensation? The receptors responsible for various aspects of somatosensation, like the ones we just described lie under the skin and at the musculoskeletal junctions; the junctions where the muscles are sort of joined with the skeletal structure. The sense of touch is communicated by several specialized receptors. Say for example, the Meissner's corpuscles, Merkel's cells, Pacinian corpuscles and Ruffini corpuscles to name a few.

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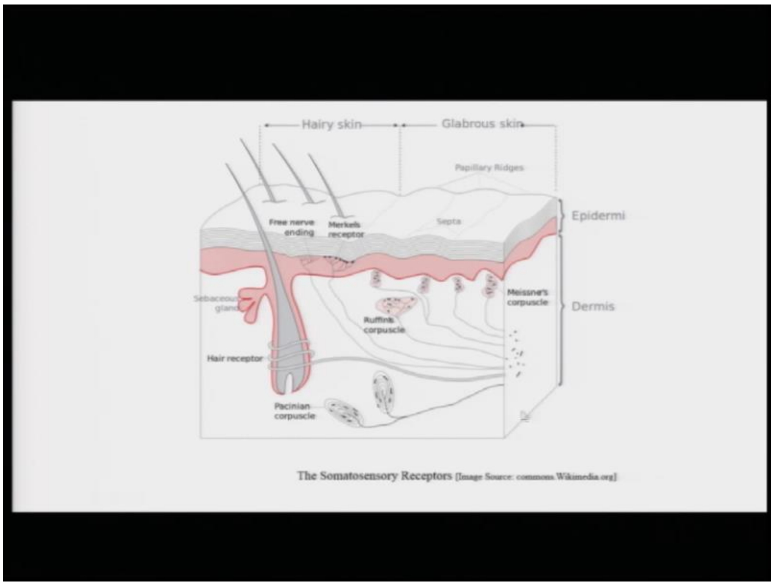

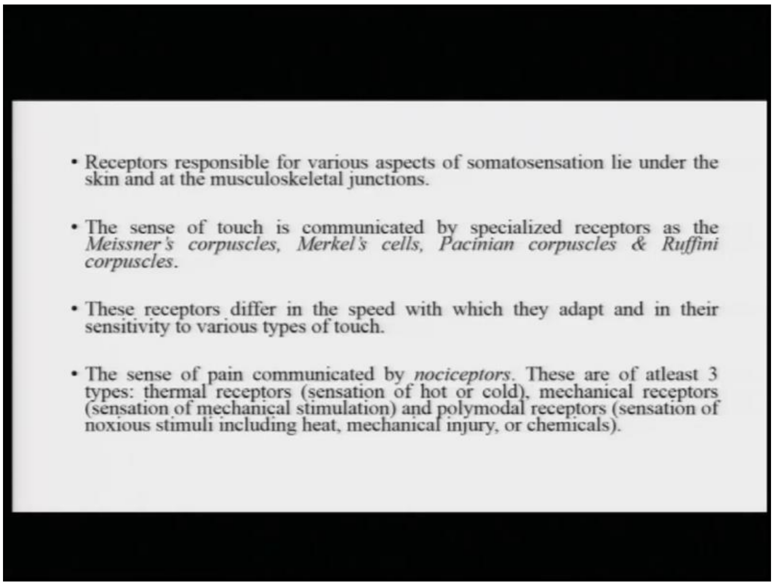

Let us have a look at the figure of them. You can see here that these are, this is basically the Ruffini corpuscles. This is an example of a Pacinian corpuscles. This is a hair receptor. And all of them are basically at the, just lying under the skin. This is an example of how this thing is under the hairy skin or how something is under where the skin has no hair.

Now, these receptors basically differ in the speed with which they adapt, and in their sensitivity to various types of touch. So, for example, you could be very softly just rubbing your hand in something or you could be grabbing hold of something with a lot of pressure and force. This sense of pain is communicated by special receptors called the nociceptors. We have talked about them in previous lecture anyways. These are of at least three kinds. So, there are at least three kinds of nociceptors that we can talk about. One that respond to the temperature sensations like hot or cold, those are called thermal receptors. Another that are mechanical receptors which respond to the sensation of mechanical stimulation, pushing, shoving, holding things.

And the third one, third kind are polymodal receptors, which are capable of sensation of different kinds of noxious stimuli like, including heat, mechanical injury, or the action of chemicals. So, this is basically a combination of several receptors that, whose action together kind of gives us the sense of somatosensation.

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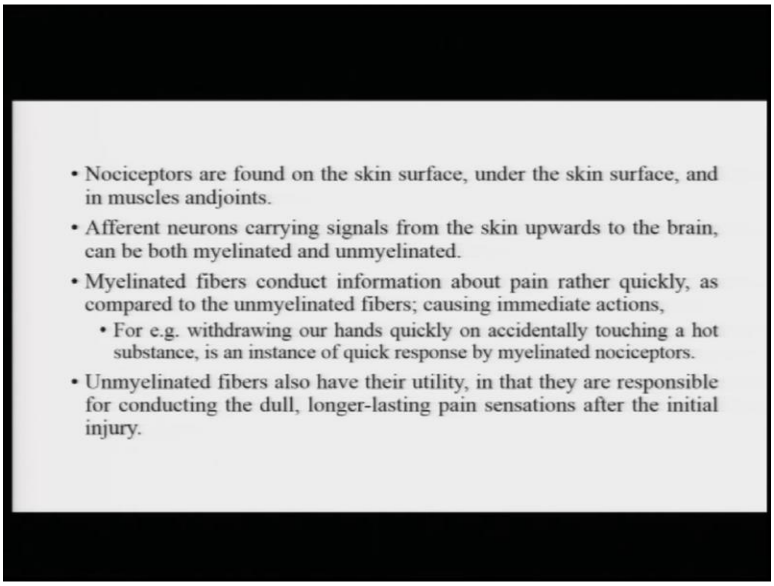

Now, these nociceptors are basically found on the skin surface, under the skin surface and in the muscles and joints. Afferent neurons going upwards from the skin to the brain can sometimes be both myelinated and unmyelinated.

You already know that, if a neuron is myelinated, it is capable of conveying signals very quickly from the point, let us say at the inner bending or at a limb to the brain. Myelinated neurons as we have already discussed are very quick at passing action potentials or neural signals. Now, in that same instance, myelinated fibers can conduct information about pain rather quickly as compared to unmyelinated fibers. And this can lead to us being able to take immediate actions. For example, if you touch something accidentally which is too hot, the myelinated fibers will basically be able to inform the brain of the temperature very quickly and you will be able to remove your hand from the hot substance in quite, in a quick instance. Unmyelinated fibers also have the utility.

Unmyelinated fibers are responsible for conducting the dull, long lasting pain sensation that continues for a few days after the injury so that you might be able to take care of the injured portion and allow it to heel.

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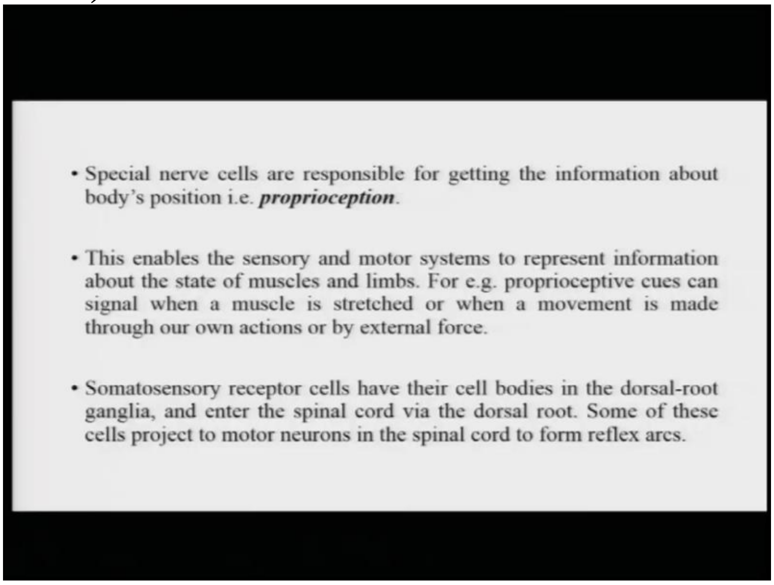

Another aspect that is very important part of somatosensation is the aspect called proprioception. Now, special nerve cells are responsible for getting us information about the body's position, which is basically proprioception.

This enables us -- this enables the sensory and motor systems to represent information about the state of muscles and limbs, where are these muscles, what are the movements, where in the space, they are at any point in time. Proprioceptive cues can signal when a muscle is stretched or when a movement is made out of voluntary action or just out of force or an external agency.

Somatosensory receptor cells have their cell bodies in the dorsal root ganglia and they enter the spinal cord via the dorsal root. Some of the cells project to motor neurons in the spinal cord to form reflex arcs so that some kind of reflex actions can be taken.

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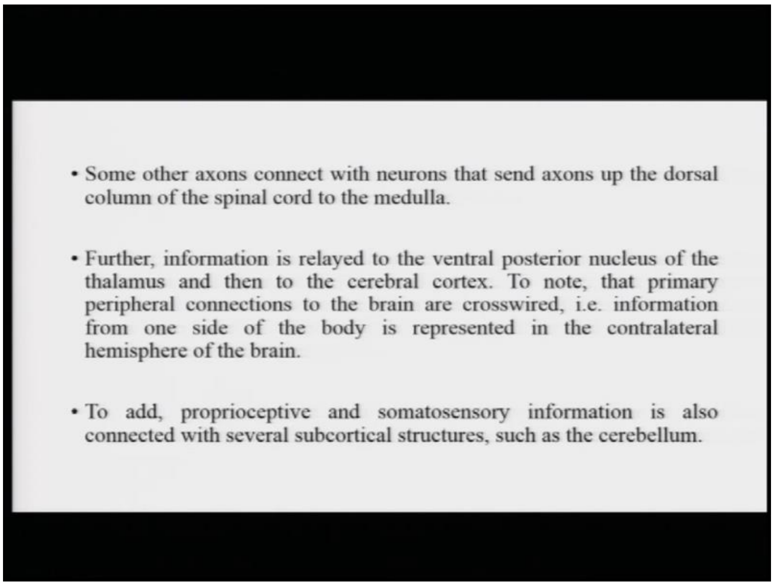

Some other axons connect with neurons that is an axon up the dorsal column of the spinal cord, up till the medulla in the midbrain. Further information is relayed to the ventral posterior nucleus of the thalamus and then to the cerebral cortex. To note the primary peripheral connections to the brain are cross wired. Basically meaning that information from one side of the body is represented in another hemisphere of the brain. Information from right side of the body is represented in the left hemisphere of the brain. And information from the left side of the body is represented in the right hemisphere of the brain. To add, proprioceptive somatosensory information is also connected to several subcortical structures such as the cerebellum, which play a very important role in movement, coordination, body balance, etcetera.

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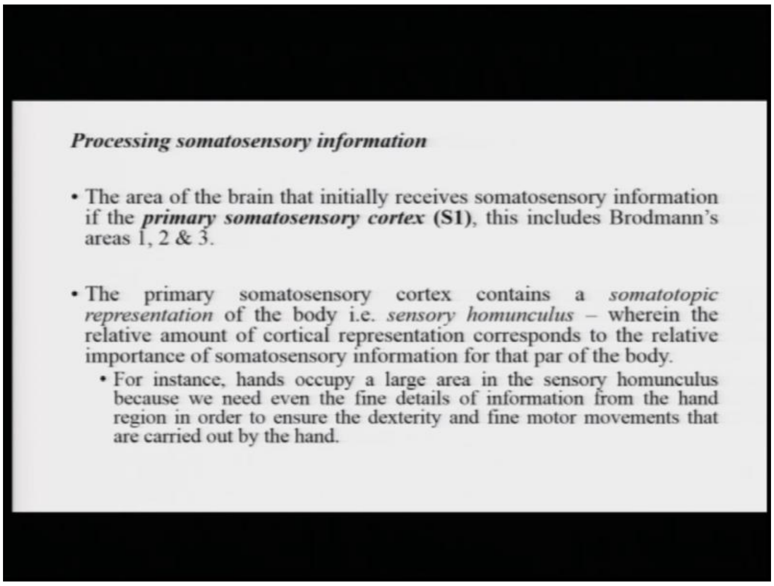

Now, let us talk about how is the somatosensory information processed. Now the area of the brain that initially receives the somatosensory information is called the primary somatosensory cortex or S1. This area includes Brodmann's areas 1, 2 and 3. The primary somatosensory cortex contains a somatotopic representation of the body, which is also referred to as the sensory homunculus.

This basically means that the relative amount of cortical representation that is acquired in the brain basically corresponds to the relative importance of the information or the somatosensory information that is arising from that part of the body. For instance, hands acquire a large amount of area in the sensory homunculus, because we need to, we need the fine details of information from the hand, from the hand region in order to ensure that our movements are correct and accurate.

This is the thing that ensures the dexterity of hand movements. And also the sensitivity of, because the hands are the primary organs which we use to explore the environment.

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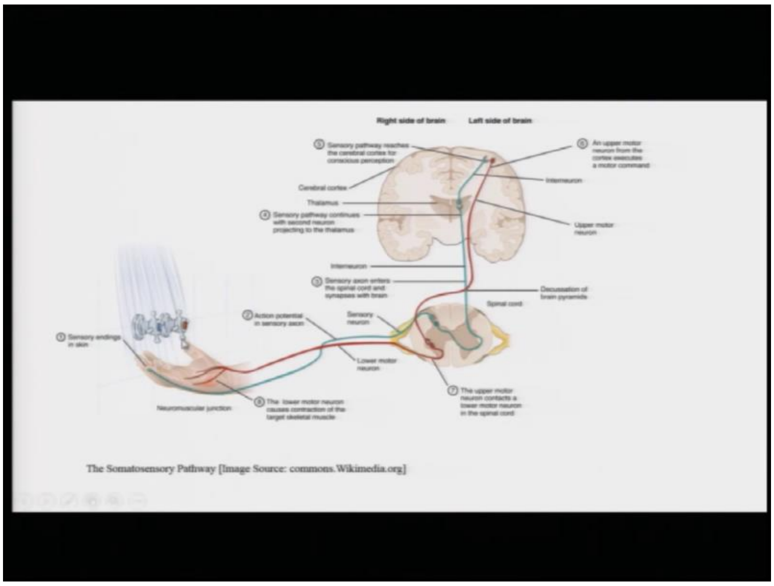

The Somatosensory Pathway [Image Source: commons.Wikimedia.org]

This is basically an example of the ascending somatosensory pathway from the limb section through this mile cord to the somatosensory cortex.

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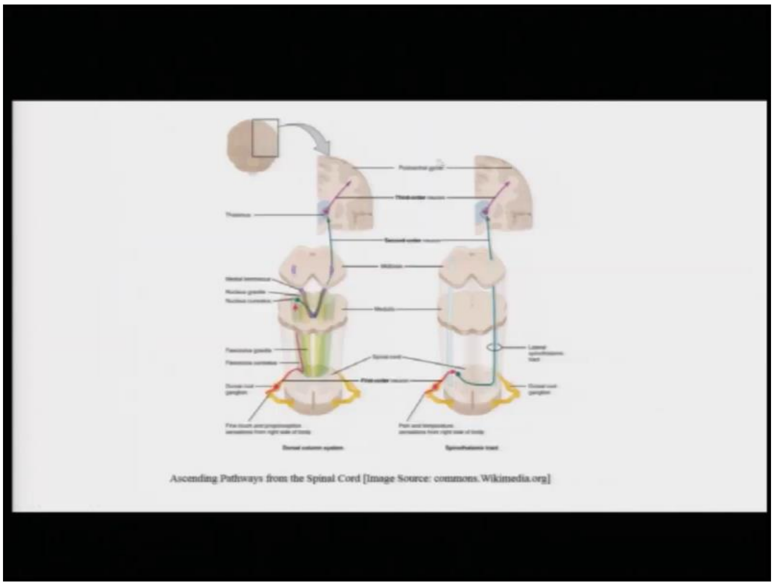
Ascending Pathways from the Spinal Cord [Image Source: commons.Wikimedia.org]

This is again the same thing in a bit of a close up.

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Here you can see the representation of the sensory homunculus. You can see that the hand area sort of acquires a large region of the somatosensory cortex as opposed to say at the face area also does that, as opposed to let us say the hip and the leg or the torso. So this is basically because these areas are used and utilized for gaining sensory as a matter sensory information about the environment and also very, very important in guiding our movements in space.

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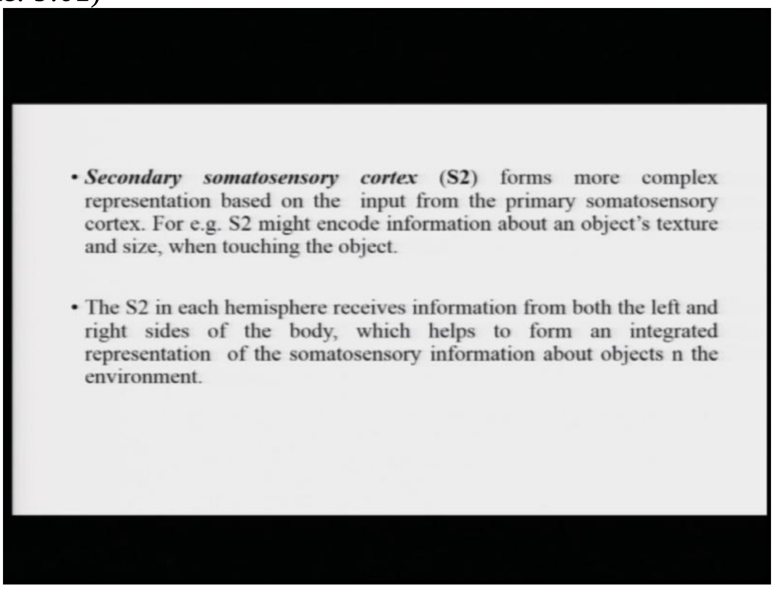

Now, the second area where the information reaches after the primary somatosensory cortex is called the secondary somatosensory cortex or S2. The secondary somatosensory cortex forms a more complex representations based on the input that it gains from the primary somatosensory cortex. For example, the secondary somatosensory cortex might include information about an object's texture or size when you are touching or manipulating the object.

Similarly, the secondary somatosensory cortex in each hemisphere is capable of integrating information from both the left and the right sides of the body, which is basically in addition, the secondary somatosensory cortex in each hemisphere receives information from both the left and right sides of the body, which helps to form an integrated representation of the somatosensory information about objects in the environment.

So, it basically, because I said that information from the left side goes to the right side and information from the right side goes to the left side, essentially, it has to be integrated somewhere so that you have a holistic image or holistic sensory impression of a particular object. This is the area of the brain that sort of integrates information from both the left side and the right side and integrates it to give you a holistic idea of what kind of objects are present in your environment.

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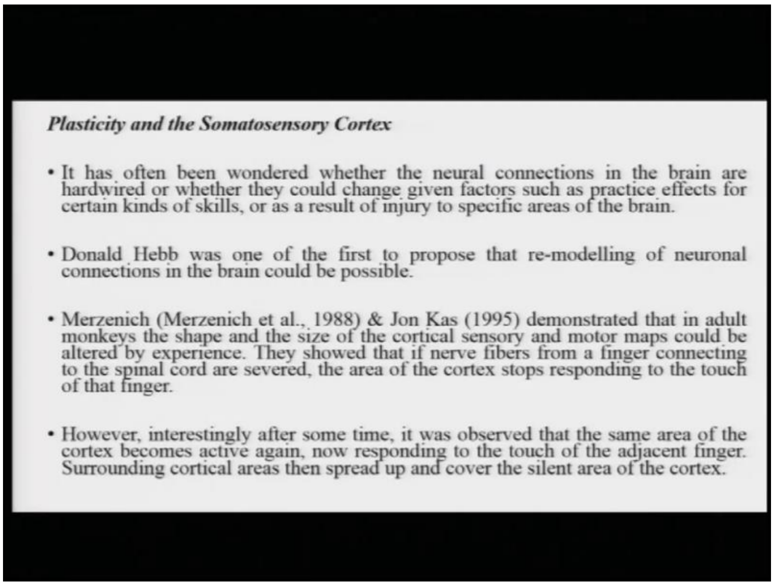

Now, the somatosensory cortex is also sort of attributed with this property of plasticity, which is also available to some other areas of the brain. But people have often wondered whether the neural connections in the brain are hardwired or whether they could actually change given factors such as practice effects, training, sets of certain kinds of skills, or sometimes as a result, injury to specific areas of the brain.

Donald Hebb was one of the first persons to propose that the re-modelling of neuron connections in the brain can actually be a possible thing. Merzenich and Jon Kas demonstrated that in adult monkeys, the shape and size of the cortical sensory and motor maps could actually be altered by experience. They showed that if nerve fibers from a finger connecting to the spinal cord are severed, the area of the cortex that was originally responding to the severed finger can be occupied by other areas, by areas that are representing other parts of the hand.

Initially, what would happen is that this area of the cortex will stop responding to touch of that finger, if it is not there. However, after some time, what will happen is that the same area of the cortex will become active again. Now only responding to the touch of adjacent finger and other parts of the hand. So, typically, what happens is that if a particular area of the cortex or say for example, an organ that this area of the cortex was taken care of, is amputated and it is not present, this cortical areas lie silent for some time before it is occupied, or say for example, covered or encroached upon by other areas, other adjacent areas, which sort of take up and fill up this space and assign it a sort of a different function.

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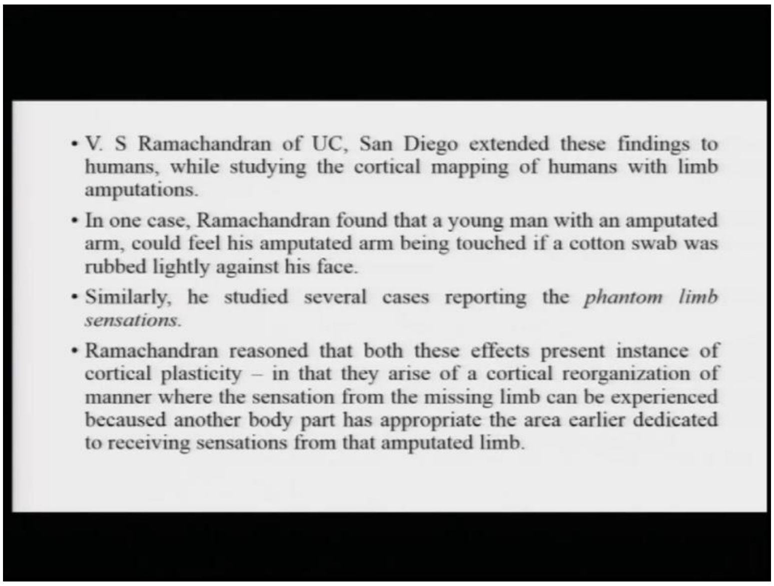

VS Ramachandran of UC, San Diego actually sort of tested these findings in humans as well. He wanted to study the cortical mappings of humans with limb amputations. In one of the cases, Ramachandran found out that a young man with an amputated arm could actually feel his amputated arm being touched if a cotton swab was rubbed across lightly at his face.

Similarly, he studied several cases reporting what are called the phantom limb sensations. Phantom limb sensations are sensations where say for example, people report experiencing pain in a limb which is amputated and is therefore not present. Ramachandran reason that both of these kinds of effects, the effect of say for example, this guy, feeling that his amputated arm is being touched by just rubbing cotton across his face are also of patients that report pain sensations in limbs that are not present anymore.

So it is basically because of cortical plasticity or the reorganization of connections within the cortical areas. The idea is that basically what happens is that sensations from the missing limb can be experienced because another body part has appropriated the area of the cortex that was earlier dedicated to that limb that has now been amputated.

So the idea is suppose for example, there is a certain area of my brain that is representing the movements in my right hand. Because of some reason, suppose my right hand is amputated, what could eventually happen is that the area of the brain that was actually taking care of sensations arising out of my right hand can basically be occupied by other parts of the body may sort of be assigned to that area of the brain, so the rewiring of connections would happen.

And eventually, what you would feel is say for example, it could be perfectly possible that I would still say for example, feel sensations whenever that area is stimulated, I will feel sensations in the right arm which is now absent.

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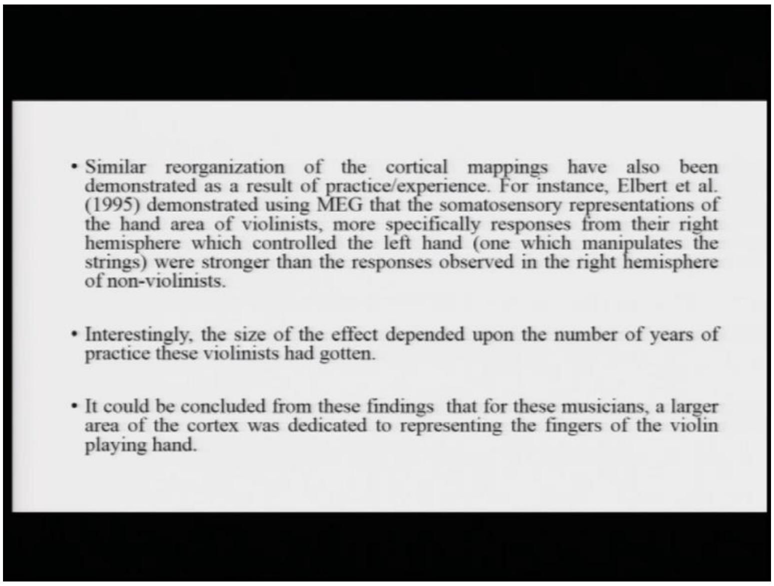

Similar reorganization of cortical mappings have also been demonstrated as a result of practice or experience. For example, Elbert et al, demonstrated using MEG magnetic encephalography that somatosensory representations of the hand area of violinists and most specifically responses from the right hemisphere that control the left hand that he use to manipulate the string was stronger than the responses observed in the right hemisphere of non-violinists, responses from non-violinists.

Basically, what it means is that because the violinists have so much experience and they have so much of practice and skill and expertise in manipulating the violin strings with their left hand, some of the area has sort of developed especially to symbolize connections, more robust connections, with respect to say, as compared to the left hands of people who do not know how to play violin or say for example, were not trained at this specific skill.

Interestingly, the size of this effect actually depended upon the number of years these violinists had spent in practice. So somebody who has just started learning to play violin will not really show this enhanced connections in the right hemisphere representing the left hand, but somebody who has let us say spent 10 years, 20 years, 30 years of learning violin might have sort of trained his brain to have those more robust connections, which enable them in turn to be very good at the art that they are practicing. Could therefore be concluded from these findings, that for these musicians, a larger area of the cortex has been dedicated to representing the fingers of the violin playing hand. So this is basically what I was trying to explain to you.

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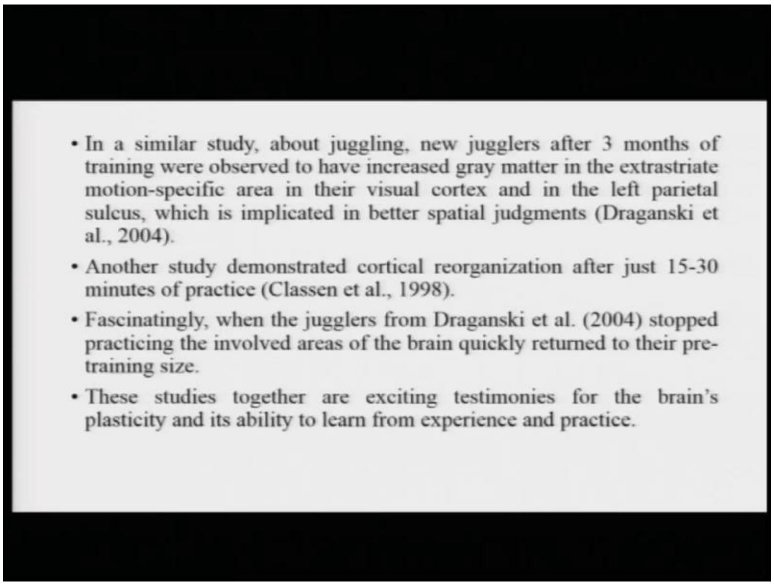

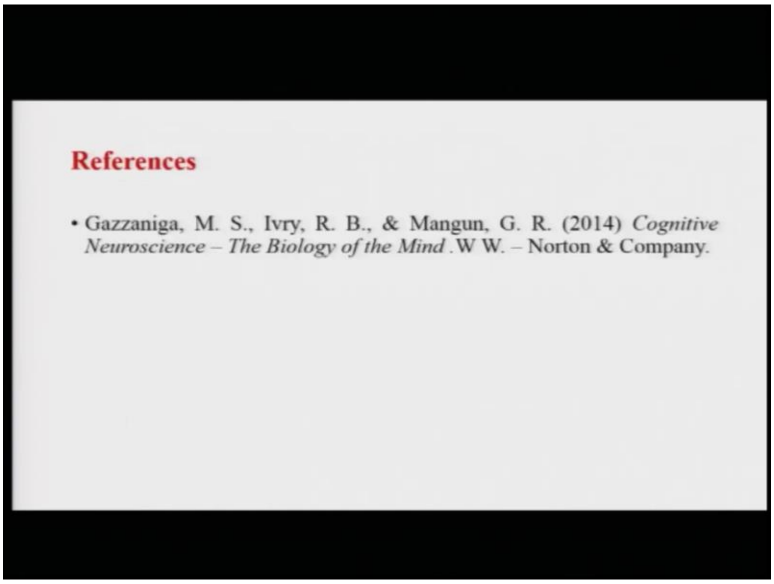

Now, in a similar study, it was shown that new jugglers who have sort of three months of training, jugglers are who, people who sort of juggle with more than two items in their hand, basically, who after three months of training were observed to have increased gray matter in the extrastriate motion-specific areas of their visual cortex, and also in the left parietal sulcus, which is implicated which is basically implicated in better spatial judgments.

So you have to sort of analyze the task of juggling, what does it involve? It involves basically better spatial judgment so that you can estimate where the ball is coming to your hand. And also some practice in observing moving objects, so that you can actually track the speed and the direction of these balls that you are juggling. Both of these skills basically are, they need a lot of practice to acquire. And what can be seen through this study is that once this practice is there, it actually causes cortical reorganization in the visual areas.

Another study, which demonstrated cortical reorganization. Another study actually demonstrated that cortical reorganization could happen just after 15 to 30 minutes of practice at a physical scale.

Fascinatingly, when the jugglers from Draganski and colleagues, the studies that I was describing a minute earlier, actually stopped practicing their juggling, the involved areas of the brain, the extrastriate motion specific area and the left parietal sulcus actually returned to their original pre-training size and the connections were sort of dissolved. It basically means that unless you keep practicing these skills, whatever cortical reorganization would have happened to aid you in those skills will actually go away.

These studies together if you sort of zoom out and have a look at them, tell us these studies can be taken as exciting testimonies for the brain's plasticity and its ability to learn from experience and practice. I think this is all that I wanted to talk about somatosensation. We will talk about the different sensory capability in the next lecture. Thank you.