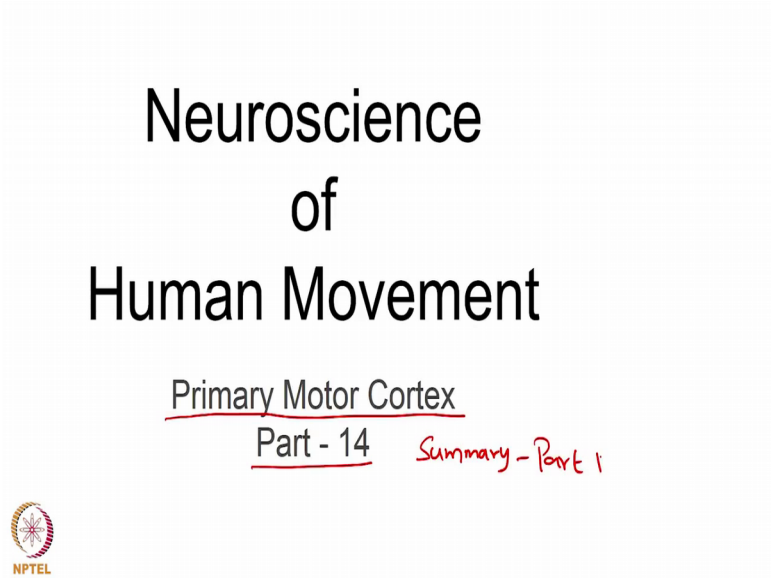
Neuroscience of Human Movement
Department of Multidisciplinary
Indian Institute of Technology, Madras

Lecture - 50
Primary Motor Cortex Part – 14

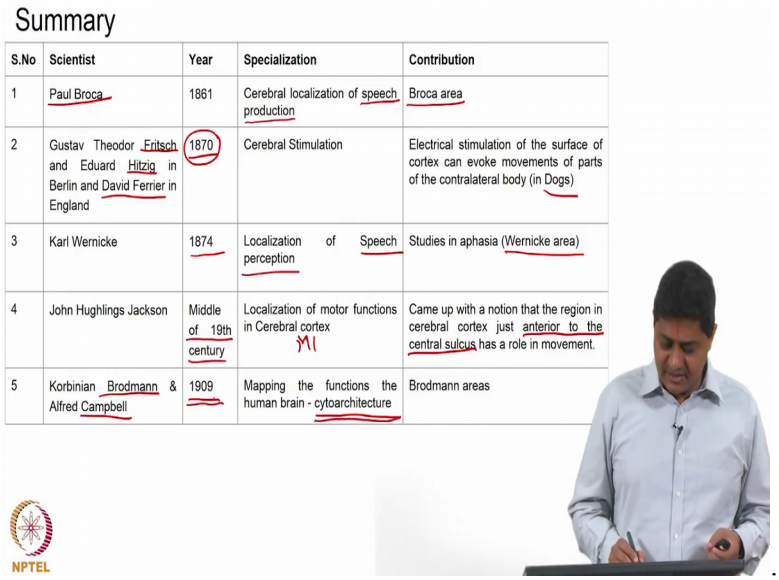
So welcome to this class on Neuroscience of Human Movement.

(Refer Slide Time: 00:15)



This is part 14 of our discussion on Primary Motor Cortex. We are almost done with our discussion on primary motor cortex. In this class and in the next class will be summarizing what we have learnt in the previous classes. So, in a way this can be called as summary part 1. So, what we have learnt is just so, much in the past 12 13 lectures that, the summary itself requires two parts. So, this is part 1 of summary our part 14 of the discussion, whichever way you want it. So, what did we learn in the past so many classes.

(Refer Slide Time: 00:49)



First and foremost historically, localization of cerebral function started with the tour around the same time, by multiple colleagues, multiple people at multiple style what Paul Broca. His suggestion that, the speech production was localized in a particular area right that is now called as a Broca's area right, then for speech perception Wernicke claimed that there is a particular region within the brain where perception of speech happens which is now, called as the Wernicke area right.

Around the same time john Hulings Jackson made a claim that would now be considered controversial for that time right. He made this bold claim that, there is this particular region that is just rostral or just anterior to the central sulcus now, called at the precentral gyrus has crucial role a significant role in moment. Now that are so, this discrete region, this discrete region just anterior to the central sulcus is now called as the primary motor cortex. But this claim was made in the middle of the 19th century, how did he make this claim. He was actually a physician treating patients with seizures.

So, based on how these patients behaved, the moments that these patients made, it seemed to him that or it appeared to him that, the seizures the way the seizures proceeded based on that, he came to the conclusion that these regions that control neighboring regions of the body must also have a neighboring control centres. This led to one thing led to another this led to further studies and finally, he made this bold claim at what would have been considered revolutionary at that time that the region in the cerebral

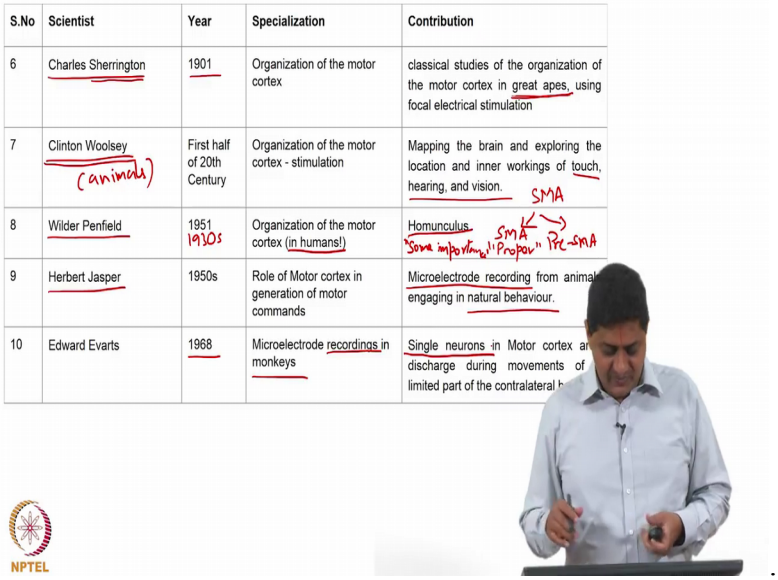
cortex that is just rostral to the central sulcus or the precentral gyrus has a crucial role in moments. This is now called as m 1 hit not primary motor cortex on premotor cortex.

Now, and in the 1870's at around the same time, David Ferrier in England and Fritsch and Hitzig in Berlin around the same time studied dogs and they found electrical stimulation of the cortex evokes movements on the contralateral side of the body. Now, that means that when a stimulate a particular area in the brain movements are produced on the contralateral side of the body means that, there must be a relationship between that site of stimulation and the moment that is being produced. Let us remember that this is 1870, this is about 150 years ago. So, for the good old days that was a very good progress that was a substantial contribution right.

And further in the 1900's in the early 19 hundreds Hanford Campbell and Korbinian Brodmann classified different brain areas using approaches of cytoarchitecture or cytoarchitectonic procedures. And what they found was that, the area that is just anterior to the central senses our rationale to the central senses was a granular. It lacked the granular structure that is typically found in other cerebral area.

So, was something was different about this area and let us note this is from the viewpoint of cytoarchitecture, not function from the viewpoint of site architecture alone right. So, based on that they found that, these areas must somehow have similar function, different from other areas right. So, once again let us remember this is the early 1900, more than 100 years ago right.

(Refer Slide Time: 05:29)



S.No	Scientist	Year	Specialization	Contribution
6	Charles Sherrington	1901	Organization of the motor cortex	classical studies of the organization of the motor cortex in great apes, using focal electrical stimulation
7	Clinton Woolsey (animals)	First half of 20th Century	Organization of the motor cortex - stimulation	Mapping the brain and exploring the location and inner workings of touch, hearing, and vision. SMA
8	Wilder Penfield	1951 1930s	Organization of the motor cortex (in humans!)	Homunculus. SMA Proper Pre-SMA
9	Herbert Jasper	1950s	Role of Motor cortex in generation of motor commands	Microelectrode recording from animal engaging in natural behaviour.
10	Edward Evarts	1968	Microelectrode recordings in monkeys	Single neurons in Motor cortex a discharge during movements of limited part of the contralateral

In the meanwhile Sherrington using his own classical approaches and he came up with this idea that, the motor cortex in great apes are organized in a certain way using electrical stimulation right.

So, basically the first are the first precursor to formal study of the organization of the motor cortex was of course, earlier done by Friction Hitzig, but a proper step by step approach a cleaner map and the organization was generated by this Stalwart Sherrington and he studied this in great apes right. And this work was continued later by Clinton Woolsey. What he did once again is a stimulation, so, he mapped the brain and explored the working of touch hearing vision and among other things. What he also found was that so, there are areas other than the primary motor cortex, are within the promoter area a particular area the area which when stimulated also produces moments this they called as supplementary motor area.

Let us remember that, later this was further classified as a supplementary motor area proper, we have discussed this in one of the previous classes this right. This is and pre supplementary motor area and then the other premoter areas are classified as a docile premoter area, ventral premotor area, printers will promoter area and the ventral premotor area itself is further divided into two areas, we have discussed this previously. And let us remember this work by Clinton Woolsey was performed on animals. And later Wilder Penfield in the 1930's 40's and 1950's studied the organization of motor cortex in

humans how can one do that! Well, obviously these were patients of epilepsy who required neurosurgery and will depend field was this neurosurgeon. So, this is data from 100's of patients. And during the surgery he stimulated certain parts within m 1 and he found that, there was disproportionate representation of hand fingers in the face when compared with the rest of the body. This he called as the little man within the within the brain of the homunculus.

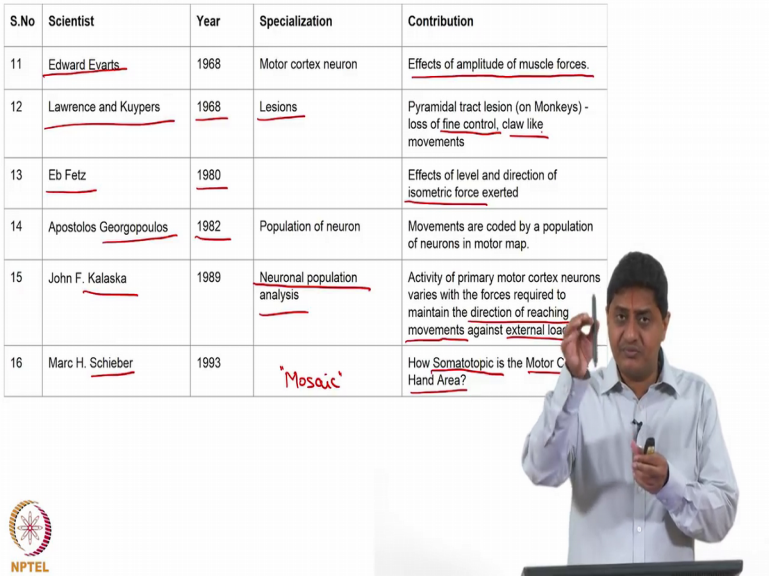
Now, we know that this little man has some importance, not completely important, so, this little man of some importance or some significance not huge significance. So, it is tempting to immediately attribute that specific area within m one directly controls this finger, this particular region and no other area controls that. Actually will depend field never made any such claim he just said that the total representation of the total representation there is disproportionate representation of the hand fingers and the face. So, that is the claim that is made, he was cautious enough to avoid such claims right, but it would be tempting for students to come up with the exaggeration someone should avoid deductively.

And then later in 1950's Herbert Jasper came up with this approach where you can record from life behaving animals. So, now that is revolutionary because, these animals are behaving as they would otherwise do. So, they are not at least they alive and moving, they are not anesthetist they are not undergoing surgery for example. And then, when they are making movements you could record the activity in different parts of the brain right so, this is micro electrode recording.

Let us also remember technology that is required for these type of approaches also developed at around the same time, in the post war period. So, there are multiple factors that has led to the development and an improvement of knowledge in this field. Then in the 1960's Edwards Evarts recorded from life behaving monkeys and he suggested that, single neurons in motor cortex area discharge during moments of contralateral part of the body.

So, once again let us remember this, this is data from individual neurons. So, he correlated activity of individual neurons with movements made by specific parts of the body right.

(Refer Slide Time: 10:37)



Further what was also found by Edwards Evarts was that he found that there was a relationship or a good correlation between the amplitude of the force that was produced and the activity that was observed in specific neurons or in specific neurons within m 1, following up on that work efforts found that in isometric force production. So, force production can happen in multiple ways, when the object is not actually moving you could still push around the object on a mechanically fixed object in multiple directions for example. So, this kind of force production is called as isometric force production, we have explained what is isometric force production or isometric regime in the previous classes.

And if it is found that the level and direction of fire isometric force also resembles how moment would have happened. So, this is similar to the actual moments and the actual forces produced during moments. So, in the isometric case there is no actual movement let us remember that so, that is the contribution of epithets. And in the 1980's a revolutionary idea that populations of neurons together encode movement features or movement related features.

So, this is you know in particular what was encoded in a centroid reaching task for example, the direction of movement was found to be encoded in the activity of multiple neurons. What is the difference between this work and your Eddie Watsworths work. Eddie watts studied activity of single neurons versus lists, here summation of activity of

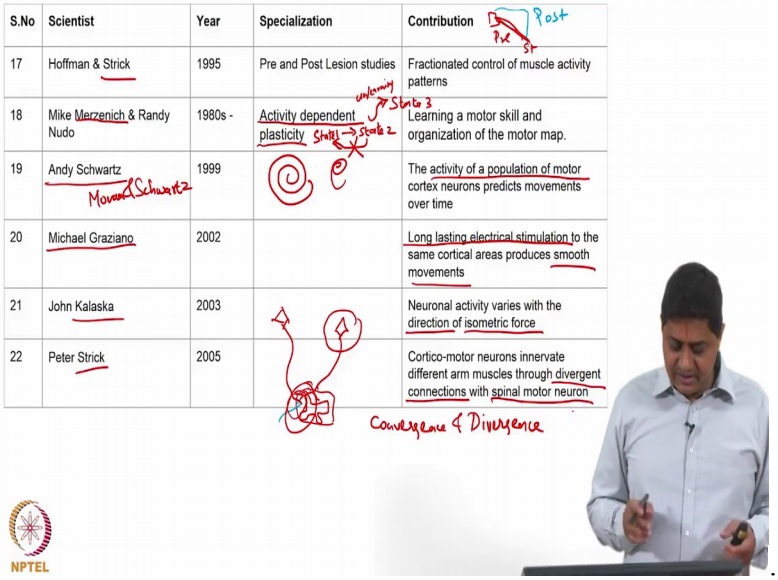
multiple neurons give rise to or give some insight into what is the actual movement that is being made or what is the aspect of momentum. For example, the movement direction in this case and Kalaska used a similar approach and what he found was that the direction of reaching moments against external loads right, against external loads also can be predicted by studying populations of neurons. Now what this means is this external load could either assist the moment that is being performed or it could resist the moment that is being performed.

Depending on whether the movement or the whether the movement is against the external load or along the external load the activity or the population activity of these neurons changed and the directions changed depending on that that is the result from Kalaska work. Then the work of Marc Schieber in the 1990's is related to the somatotopic in the m 1 one area, brilliant work. Studying a crucial work in this field, studying the contribution of individual neurons or groups of neurons within the m 1 region, what was found was that neurons that control movements of individual digits were not necessarily restricted to a small area, but rather there present in multiple areas.

Not necessarily in one area, they were present in relatively large, they were distributed in a relatively large area of m 1. Also what was found was that, neurons within a region controlled not just one digit sometimes control you know more than one digit several digits at the same time.

So, what was found was that there was not a region to region, a region to effector, one to one relationship, but the relationship that was found was rather mosaic. There was both convergence and divergence, this theme I will continue in one in some of the later sections also I will discuss this topic of convergence and divergence ok. And in the meanwhile there was this work of Lawrence and Kuypers, where they studied lesions what they found was that, lesions pyramidal tract lesions on monkeys the resulted in devastating effect of loss of fine control and claw like moment. So, objects that were picked earlier with the precise moments of the index finger and the thumb were now, pick with the whole hand moments or claw like moments right.

(Refer Slide Time: 15:31)



And later there was this work of Peter Strick, it where he studied pre and oscillation and showed that, pre lesion the movement was diagonal as expected and suppose that was a target and that is a start right. If that is a moment that needs to be made that a smooth movement before the lesion, after the lesion the movement was you know like that remember this picture from one of the previous classes right.

So, this is post and the red is pre lesion ok that is pre. Then, comes the revolutionary extraordinary contributions from Mike Merzenich expand, his trainee Randy Nudo talking about plasticity. This concept is revolutionary has important crucial implications for rehabilitation. So, what they found was that, there was use dependent or activity dependent plasticity. So, if people learn as people learn that is reorganization as they unlearn and forget there is the organization, let us remember one thing, so I will briefly summarize this situation.

That is a state one, before learning this is the state of the brain before learning and then the monkey are the human learns a particular task. Then they go to state two. Then let us see lets somehow assume that they have completely forgotten or unlearned that task. You would expect that the brain would go back to state one, but that does not happen usually, what happens that there is a new state that is achieved that is state three this is after unlearning. This means that the brain is continuously remodeling itself, so, there is dynamic alterations in the brain structure as we go along.

Then the work of Andy Schwartz, their activity of a population of motor neurons can predict the actual trajectories of moments. Let us remember this case where, there was a spiral that had to be made from inside to the out or from out to the in like that for example remember that case. From these velocities instantaneous velocities can be extracted and population vectors can also be used to rebuild this trajectory and the predicted trajectory from population vectors closely resemble the actual trajectories.

This was the study that we discussed that was Mornun Schwartz right. Please revise this as we go along, I am just briefly touching upon what was already taught then, the crucial contribution of Michael Graziano, so what was found long lasting electrical stimulation very different from other classical neuro stimulation methods, a few milliseconds was the time that is used.

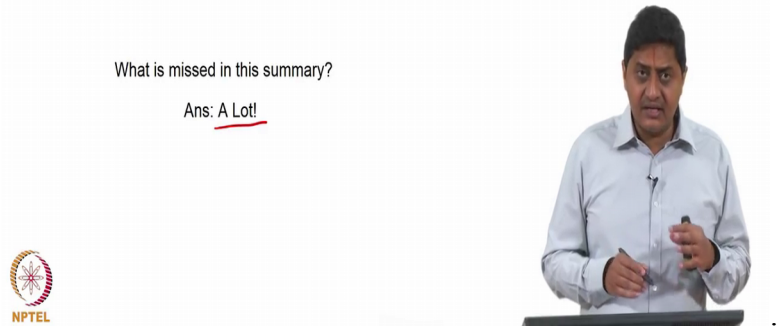
In classical methods in this case long lasting electrical stimulation, several 100's of milliseconds produce well coordinated smooth movements, we said this. Defensive postures are hand to mouth moments. Let us remember a hand to mouth movement involves movement at multiple joints and that means, control finally, coordinated temporal and spatial control of multiple muscles.

This was achieved by long lasting electrical stimulation a revolutionary idea this. And continuing along what was also found was that neuronal activity depends on the direction of the force this is Kalaska work and then, Peter Stricks work more contribution from professor Strick. What he found was that there was, divergent connections, from cortical motor neurons to the spinal motor neuron. So, what this means is that, so if there is a cortical motor neuron here, there is suppose what does this refer to, this refer to the spinal cord of the same drawing the classical spinal cord pictures. This could innervate multiple areas so, this cortical motor neurons can innervate multiple areas.

And also remember one area can receive input from multiple neurons right. So, what this means is that, there is convergence of so when you look at it from the spinal cord point of view, at a particular point several motor neuronal inputs may converge and from the viewpoint of the motor cortex, regions are from a relatively small region within the motor cortex inputs may go to several areas are divergent. So, there is both convergence and divergence in these connections. This also we have discussed in the previous classes in relatively good detail so, please do go through that.

(Refer Slide Time: 21:03)

S.No	Scientist	Year	Specialization	Contribution
23	Darcy Griffin	2008		The activity of some primary motor cortex neurons can be correlated with particular patterns of muscle activity.
24	Bizzi	2000s	Learning, among other topics	Specific neurons are responsible for change of directional tuning during learning



And more recently in the 2000's what was found was, motor learning or in particular this is learning to respond to perturbations right, to specific perturbations and recording from neurons, it was found that, the change in the direction to tuning of learning was only specific neurons where making changes to directional tuning curves in specific directions, but not other neurons. There were other neurons that were responsible during the war short period, there were some neurons that were responsible during the early learning period or early change period and there were some neurons whose activity did not change right.

So, this is the work of Bizzi that we discussed in one of the previous classes. And then, also the work of Darcy Griffin, when he said that activity of specific m 1 neurons can be correlated with specific patterns of muscle activity of specific muscles. So, this is a very brief summary of the work that we have discussed in the past several classes. What is missed in this summary, actually a lot is missed in this summary. Knowledge in this field has come through the work of several 100's if not 1000's of researchers.

I have only summarized the work of about 24 researchers here. So, the idea here is to, use this opportunity to continue to learn. So, I have summarized what we have discussed in the previous classes, by no means this is justification of the actual contribution of various colleagues and this is also not enough justification for the amount of knowledge

that. This is just the beginning of learning. So, with this we end the discussion on primary motor cortex and studies of the primary motor cortex.

Thank you very much for your attention.