Neural Science for Engineers
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Lecture - 46
Movement: Role of Spinal cord

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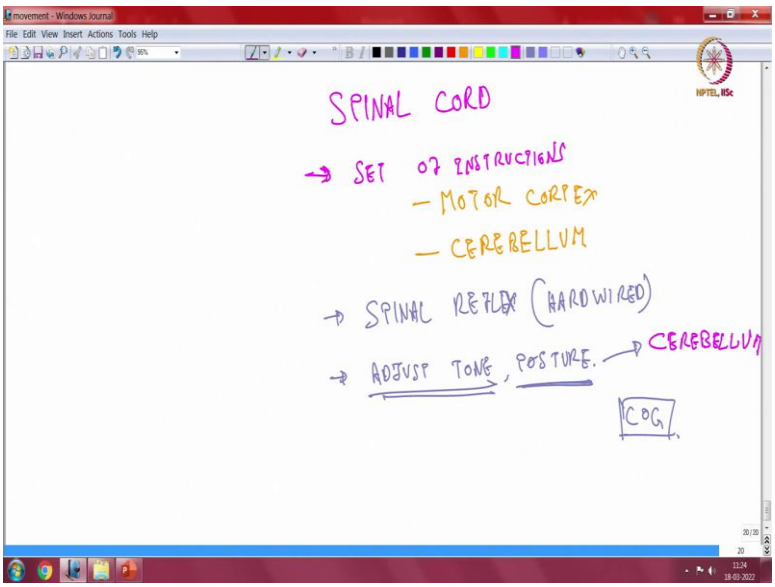

Now, from there it goes into the Spinal Cord. So, the spinal cord receives set of instructions from motor cortex then from the cerebellum. So, motor cortex and cerebellum and now this spinal cord has so many other stuff to do. So, as I told you it is just spinal code is not just about being a conduit for information transfer to one to another. So, that when the data comes to this spinal cord you need to set a lot of other parameters. So, you would activate the spinal reflex mechanisms the which are hard wired you know and you also need to you need to adjust tone and posture.

So, when my arm is moving away from my body; obviously, the centre of gravity changes right, centre of gravity changes from what it is at present to something which is different arm weighs quite heavy you know of 60 or 70 kg that a person is arm has a definite weight and when the arm is moving forward it is not just static event dynamic event.

So, the forces generated are different and to ensure that my body remains in it is equilibrium poise during that. So, you need to generate mechanisms by which you can

have to adjust tone. Now, tone also refers to posture, posture also goes back into cerebellum where further changes happen. So, that is something which you need to remember for the next part of the story.

So, revising we started with a simple task which is you know not a simple task it is actually a complex task of a three step process of going reaching an object picking the object and putting it into a different into a different destination site. So, we started with the frontal lobe which splits up the task into logical this one, does checks and balances that you know whether it is safe to do. So, whether it is required to do. So, whether it is you know all those high level tasks and then it splits up into individual coordinated coordinate individual sub task.

Now, people who have frontal lobe dysfunction are able to identify pens, they can identify the object, but they are not able to do this sequential events you know you go reach the object pick it up and put it into the shirt pocket is a difficult task when patients have frontal lobulation. So, that is how we understand that the frontal lobe is involved in this kind of functions.

Now pre motor cortex, pre motor cortex breaks down into some sets of sub task you know each task is broken down into task it is fed into the specific regions within the motor cortex along the motor homunculus and from the motor homunculus the data goes into the cerebellum. It goes into the basal ganglia data is again picked up from the basal ganglia goes in the cerebellum also gives back some data into the motor cortex, a little bit of the gain is calculated and the entire data from the motor cortex and the cerebellum goes down into the spinal cord.

Now, why it split over here is patients with cerebellar diseases also have an important role in not a role meaning in the sense that patients with cerebellar diseases have something called as hypotonia. So, tone which is responsible for posture you should remember stuff from my previous classes on muscle in which I had explained how tone is generated gamma, gamma motor neurons, alpha motor neurons and the spindle and the loops.

So, please do revise that if in case you have forgotten. So, tone as a entity is controlled not only by the spinal cord, but also by the cerebellum. So, the cerebellum ensures that this movement this part of the task is executed fluidly, you know you do not lose your

balance when you reach for an object. So, that is because your tone is subtly adjusted your center of gravity still remains in the same place when your arm is reaching out away from your body and reaching out to an object. So, you need to have minute adjustments in tone.

The spinal cord executes this thing through this set of you know hard wired spinal reflexes. So, when the arm is moving over that side there should be muscle tightening on the opposite side, which basically indicates that these muscles are static you know I do not bend like this when I reach out for an object on the other side. So, that is done by ensuring that the muscle contraction subtly increases. So, these are isometric contractions.

So, isometric contractions are contractions in which the tone of the muscle increases without the changing in the length. So, these changes happen on the opposite side of the body when you are reaching out to the object and that is determined through this spinal reflexes. So, we have reached up to the spinal cord. So, what exactly happens within the spinal cord is you need to; you need to; you need to activate sorry.

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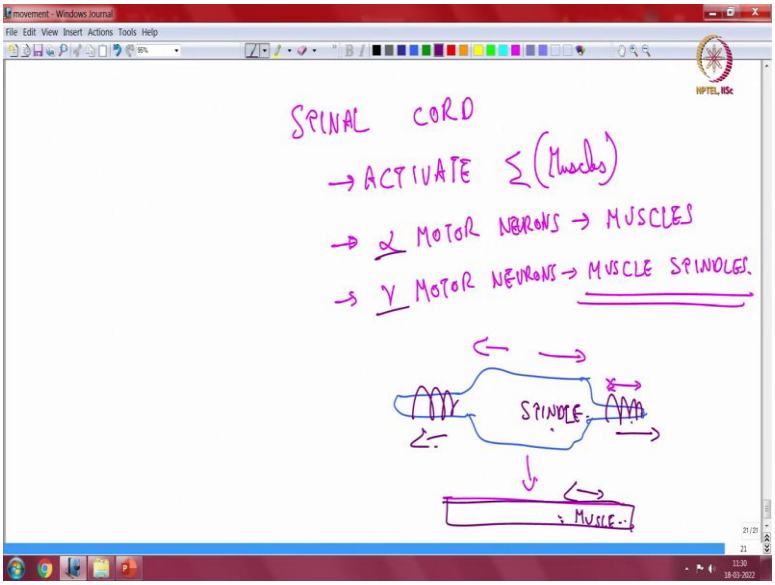

Activate set of muscles so, there is a set of muscles which are to be activated and which muscles are to be activated is sent from the motor cortex. Now, that goes through that is to be done through alpha motor neurons, which go to muscles, you also need to send it through gamma motor neurons which go to muscle spindles. I have explained this in my

prior classes to how gamma motor neurons are through the spindle fibres. So, muscle spindles are just revising.

Muscle spindle fibres contract you know reduce in length this increases in length and that in turn causes contraction of the muscle, this is the spindle ok. So, if you do not do that you know you do not do the alpha and gamma simultaneously when the muscle contracts the spindle reduces in size and that reduces the output of this spindle and that in turn prevents the muscle from contracting further.

So, you need to; you need to activate the gamma neurons and that is the muscle spindle muscle to ensure that there is smooth and coherent contraction between the of the muscle for the entire duration of time. So, the spinal cord does that. So, the spinal cord gets the tone information from the cerebellum, the spinal cord has internal mechanisms of regulating the tone.

So, the gamma knife sorry the gamma neuron has to get the tone information first sends the information to the spindles to prepare for the action the other side muscles which require tone to be increased they have a spurt in gamma output, the actual task of muscles which need contraction go to the alpha motor neurons.

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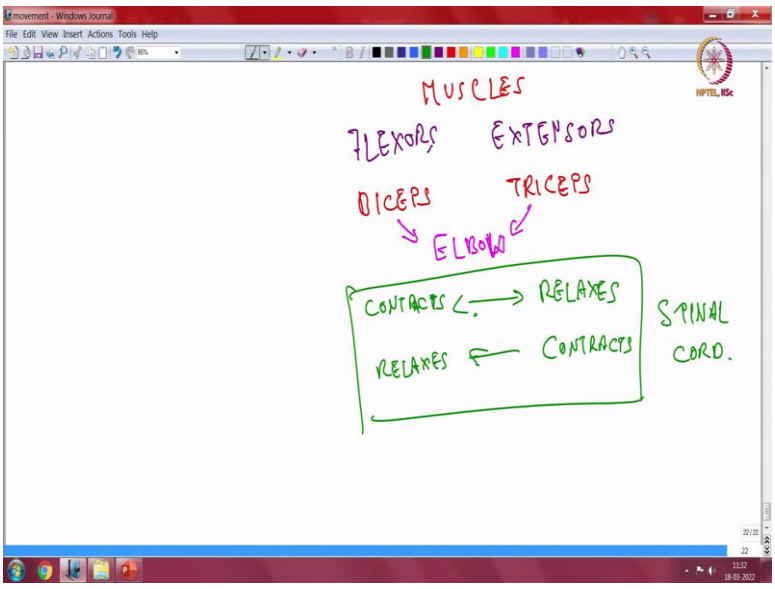

The other task what happens over here is, if you remember we had spoken about flexors and extensors which are different groups of muscles. So, if you have biceps, you have

triceps using these terms because it is more commonly understood. So, you have biceps in front of your elbow and then the triceps behind and elbow is the for the elbow. Now when biceps contracts triceps relaxes and vice versa. So, when the biceps contracts triceps contracts it causes relaxation in the biceps.

So, this wiring you know this wiring is in the spinal cord ok. So, that is how you know the this set of tone adjustment posture adjustment and which muscles have to contract and which have to relax is determined in the spinal cord. Remember the frontal lobe has nothing to do with all of these thing these are governed at individual segments local segments within the spinal cord.

So, between two or three segments you have this entire task which is accomplished as to which set of more muscles have to move and which set of muscles have to relax how is the tone to be adjusted across the rest of the body is also determined within the spinal cord and in this cerebellum. So, that sort of completes this very complex task of reaching an object.

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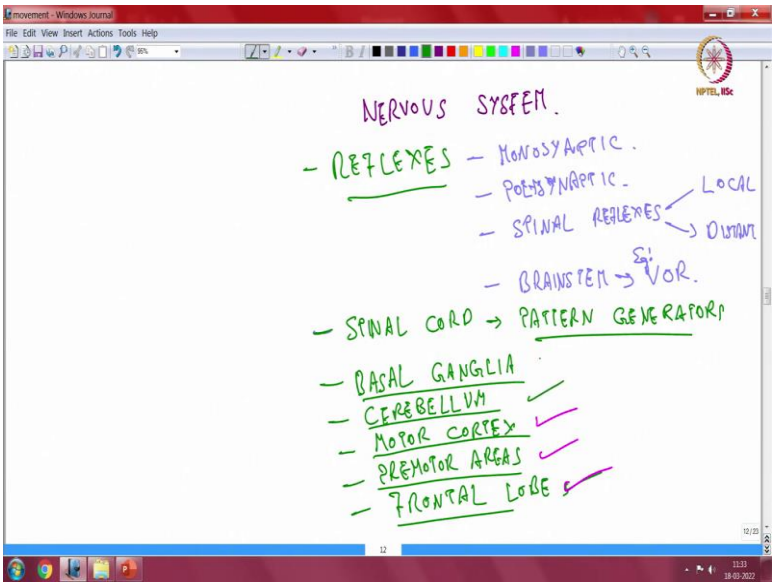

So, we have discussed each of these individual elements which are there in the context of a task. So, how each part of it contributes to a every single task is what has been what had been discussed. So, you have got frontal lobes, pre motor areas, motor areas, cerebellum, basal ganglia, spinal cord individual reflexes which are within the muscles

which act as limiting factors for you know preventing so and that results in the smooth reach and pick up of an object consistently.

You do this every day whether you are holding a tooth brush toothbrush, riding cars, two wheelers, you know reading text, viewing a video all of these are motor tasks breathing it is a motor task. So, all of these are very coordinated fine activities none nothing trivial about it at all and this is the sequence of events which are responsible for the whole activity. So, pattern generation I think I need to spend a little time on pattern generator and I think that should cover up this part of the topic.

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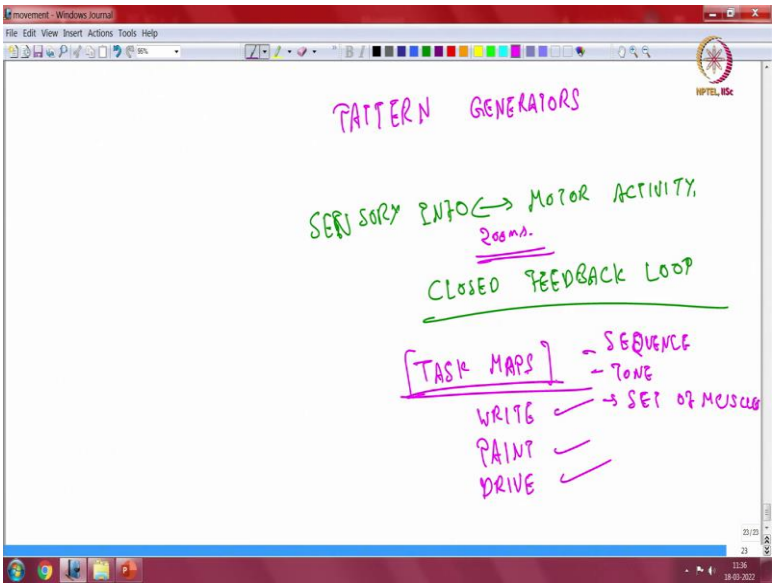

So, I will start out with why you need pattern generation. So, we discussed the important role of the sensory you know sensory info which is required for coordinating motor activity so that would form a closed loop. So, that is a closed feedback loop. So, its closed you got sensory info which goes into motor activity the motor activity in turn generates sensory info and that is used to regulate and that is how it should happen.

Now, what happens with it is you know you cannot have all motor activity in closed feedback loops because the total amount of time which is apparently required for this complex processing is about 200 milliseconds, you do several tasks which are under 200 milliseconds. So, how do you ensure that these tasks are implemented without having this you know live online coordination and control.

So, two mechanisms one is you know there can be task maps. So, you can set it out as a task. So, higher level you know say for example, write is a higher level task. So, you can write, paint, drive, remember these are all learnt things.

So, that is what I meant by task maps. So, task maps is not just about sequence of events, but it also would be say set patterns of how much tone changes need to be done, which set of muscles are to be stimulated activated. So, you can have task maps, now why task maps are important because if you recollect as I told you anything with writing sports or any such task is learnt.

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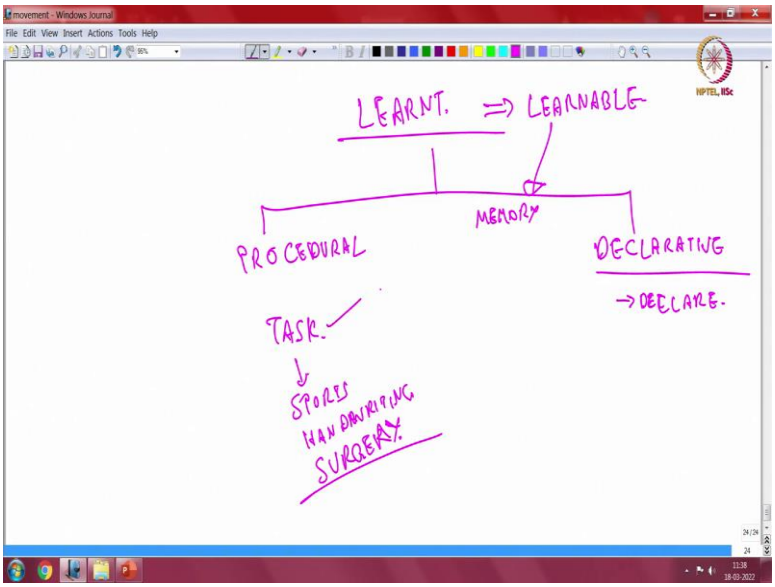

So, learnt implies there is something learnable. So, learnability of a task exists and in here you should what is that you should know procedural and declarative. I am mixing up stuff because it is relevant that you understand this these entities like what has been discussed. So, declarative is you declare you know you initialise with values. So, that is how you declare an object.

I have learnt to pick up a pen, I have learnt to write in English, I have learnt to you know I have there is some overlap incidentally which is the reason. So, those are you know you have declared items in sequence and that is how you run it in your head and that is declarative memory.

So, learning and progressing onto to memory, procedural is a task based. So, you have a task which you repeat, repeat, repeat for example, any kind of sports handwriting surgery. So, you learn by doing now it is in that context.

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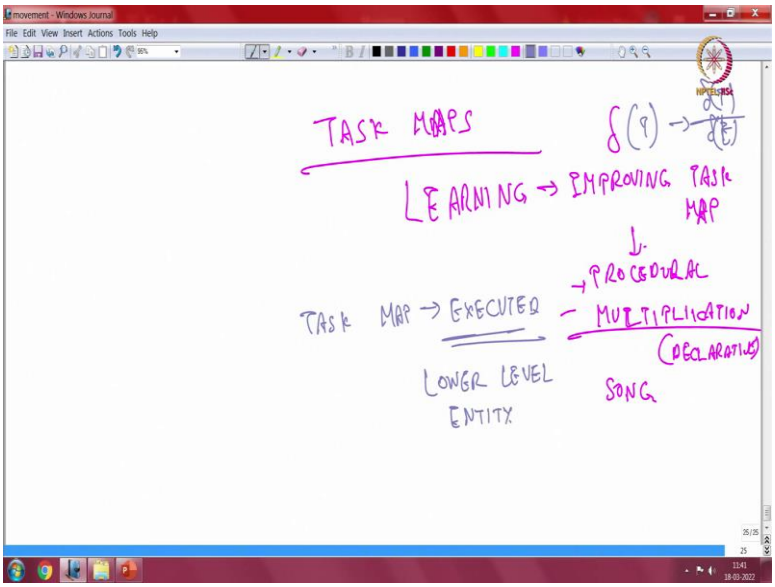

So, when you have this kinds of task you need to have this maps. So, you have task maps which are built. So, task maps are actually lower level stuff say for example, driving a car, driving a car would require you to handle the steering the accelerator brake and the you know foot pedal changes within the accelerator and the brake and the clutch and changing the clutch.

So, these are task maps and the learning part is in improving the task map generally seen with procedural memory, but also say for example, you are learning multiplication tables which is declarative memory multi. So, multiplication is declarative or learning a song you know. So, there is a song of course, it is there is some there is some procedural also because there is tone and face and so many other things. So, I will just put it as learning a poem in which you have got only text which is I hope there are no poets in the audience.

So, what I meant is here there is a task which is change and that task is change in time and that constitutes the mechanism of learning. So, you improve with time on some particular task. Now at the end of your learning you have a task map which is executed, now this is a low you know lower level entity. Lower level entity in the sense that you know it does not need to go through the frontal lobe to split it into those components.

So, the frontal lobe instead of executing it is like you know calling a function I think that is the better way for this audience. So, you instead of writing function in your program every time you just write the path to your library where this function recites function recites.

So, yeah a function recites and that function is written up in one of your other files or in some standard library and you call that function into your program. So, similarly for in the human brain you have got this task maps which are generated, these task map give the exact parameters which have to be outputted to various parts of it.

So, say for example, the cerebellum knows that when you are driving a car how much of steering wheel has to be turned, the spinal cord knows when you apply pressure on the clutch pedal how much of tone has to change in the rest of the body. So, that your body does not lurch forward or backward when you each time you apply the press on the clutch pedal. So, those are you know those are kinds of tasks which are pre programmed.

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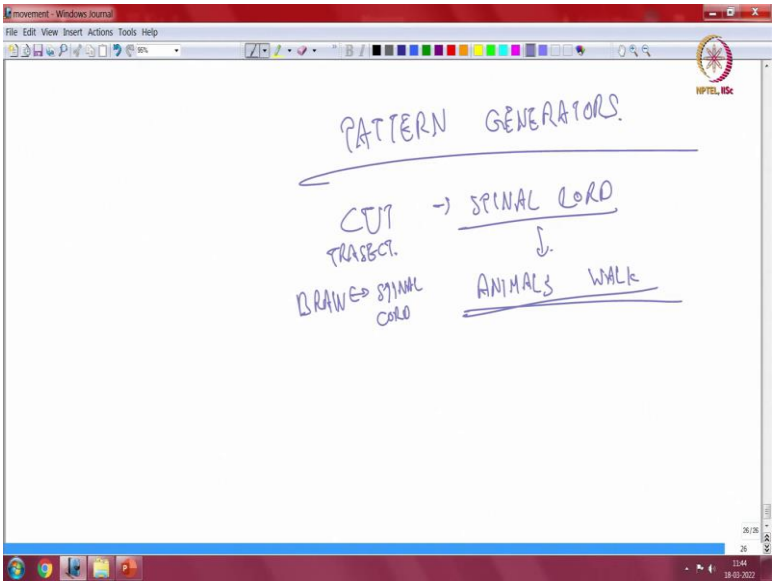

So, when we go into these are learnt you know we go into something more complex which are pattern generators. So, interesting experiments though (Refer Time: 21:10) were done in which you section spinal cord and animals and in spite of which animals can walk. So, there are animal experiments in which you cut or transact brain from the spinal cord and animals walk with that.

So, what I want to convey is see, so far what I have explained is how the brain and various parts of the brain is important for generating purposeful activity, but here I am just saying that animals with just spinal cord are able to walk, walk is a very complex activity you got sequential activity of all 4 limbs now that is where the role of this pattern generator.

So, when you say walk, walk is something which is very intrinsic it is not learnt in the sense of the terms which I was using you know it is not declarative you do not it is procedural memory, but it is very intrinsic at a very fundamental level hard wired. So, pattern generators exist within this spinal cord which are able to you know do this coordinate coordinated method coordinated sequence of activities irrespective of higher control.

So, that is how you know you have a pattern generator. So, when you are walking and talking you are doing pattern generator at this spinal code level and then the talking is happening at a higher level. So, you can mix and match various tasks super impose them, phase them, sequentialize them. So, those are the; those are the; those are the advantages of having pattern generators.

And I spoke about task maps which are methods by which you can learn, you have a task map and you update your task map with each subsequent training and that results in improved task performance sometimes even worsening task performance as you would see in an (Refer Time: 23:24) So, that is speaking from personal experience.

So, that is something about the overall way in which movement happens within different parts of the nervous system. I have mentioned in brief the brief this entities I think a little more brief from the medical context is relevant because you should know something about disease process to have a better understanding. I spoke to you that you know what we know of these function you; obviously, cannot put an electrode into somebody's basal ganglia and then find out what that part is doing or what part that part is not doing.

So, what we do in the medical side is we observe in patients diseases try to correlate with findings in MRIs imaging or maybe post mortem, specimens earlier and try to link or correlate between you know. So, there is a disease in basal ganglia people have this kind of disease. So, the function which is lost is this that is what I am trying to say.

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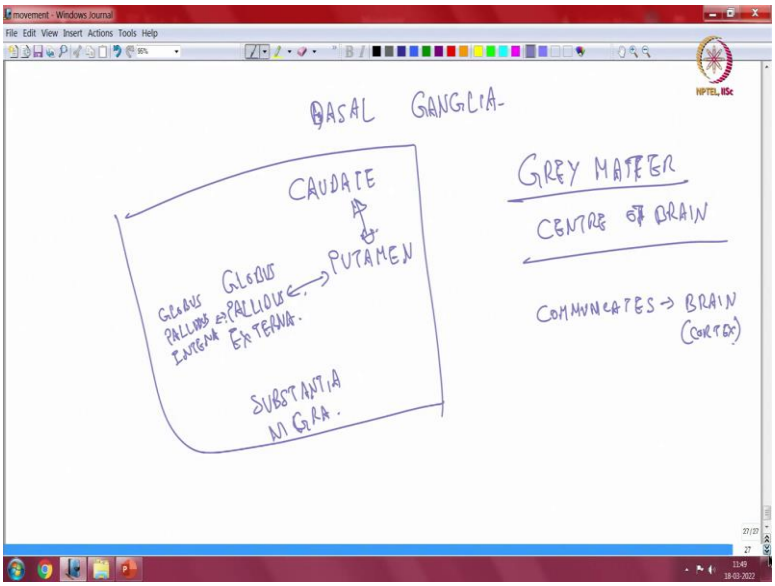

Now, I will start with basal ganglia, box diagram I have explained this in my anatomy classes I am not revising the entire stuff. So, these are the components of the basal ganglia and the substantia nigra, the whole stuff is called as basal ganglia caudate and putamen are very closely connected to each other globus pallidus and interna is connected close to each other and so this sort of is the general picture and substantia nigra we will go into the connections in a little more detail subsequently.

Now, how what do we know. So, these are this is all grey matter centre of the brain and so this is this communicates with the cortex. So, that is stuff which you should know before I actually go into a little more detail on this topics.

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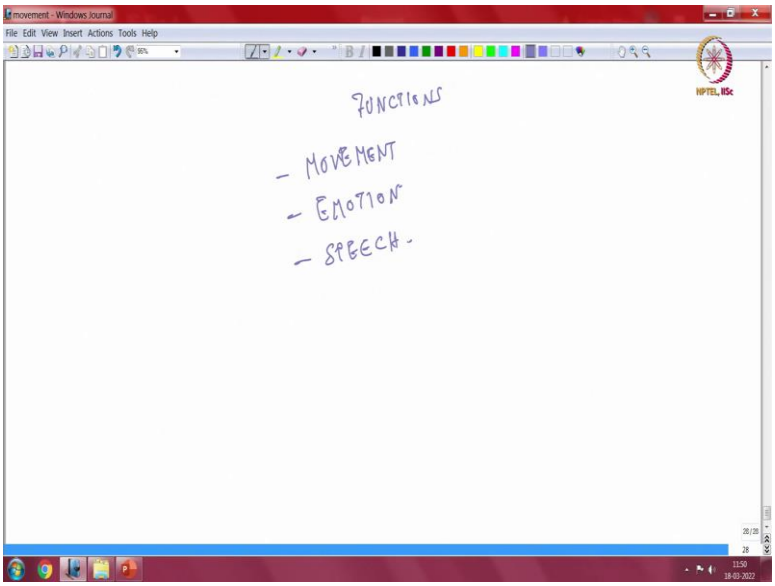

Now, as I told you it is important in movement, but so functions are movement control, you have emotion control and speech. So, how do we know all of these things?

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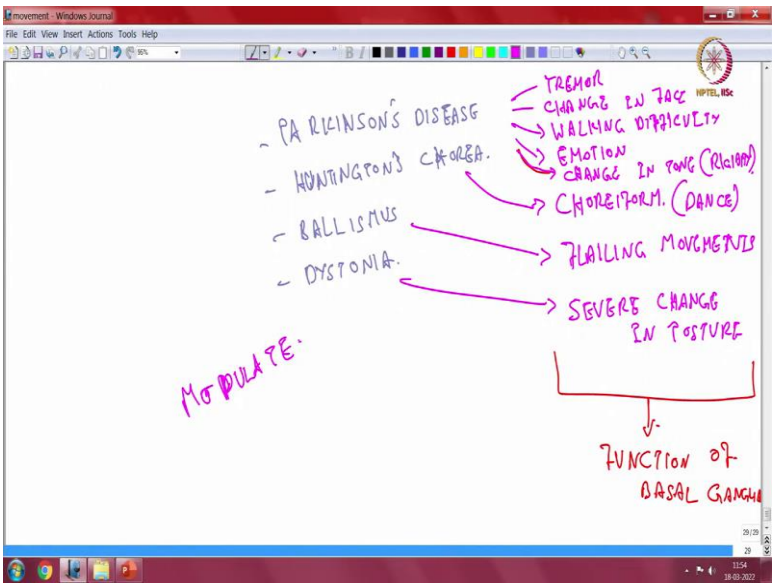

So, we look at couple of diseases, the most popular one is Parkinson's disease syndrome, then huntingtons chorea, ballismus, dystonia of course, not it can be part of some of these things. Now, if you look at you know disease manifestations you got tremor, then you have change in the face difficulty in walking, then there can be changes in emotion, we go in to chorea it is choreiform movements dance like movements, you got ballismus

which are flailing movements and dystonia is what you call severe change in posture. So, this entire set is the function of basal ganglia.

Tremor, tremor is you know you have a change yeah I forgot there is a change in tone which I have not written which is which is also very important tone which is rigidity. So, tremor is there is a; there is a continuing fine movement of the arms, limb arms, limbs, face which is seen in Parkinson's disease.

So, avoidance of tremor; obviously, is a function of the basal ganglia, but what would you know why how would you look at tremor. So, tremor is a perturbation about the normal, you know you keep your hand like this and there is a tremor which you can actually see manifest if you have lifted a heavy object for quite some time you would see if those fine kind of tremors that is not Parkinson's, but that is due to fatigue. So, there is a; there is a subtle change in the you know control of the gain for that particular posture. So, that and loss of that you know control is what is manifest as tremor.

So; obviously, the basal ganglia is involved in the in preventing tremor in the smoothness of the movement. Now changes in the face emotional liability are things which say that they are not just responsible for movement as a physical manifestation a physical in the sense that it is not an actuation issue it not just involved in actuation, but also in involved in emotion in you know those manifestations of emotion which are lost when the basal ganglia are involved.

Walking difficulty is another example. So, walking as I told you it is a pattern generator which is located somewhere in the spinal cord, but then you know the function of walk is impaired because of basal ganglia. So, they modulate I think that is the correct term. So, basal ganglia modulate activity.

So, modulation happens by the various parts of the basal ganglia and that is what gets lost. So, tremor can be only in the limbs. So, there is action tremor in which when you reach an object you have tremor there is resting tremor in which when hand or leg is at rest you have fine movements.

So, all of these have are manifestations of Parkinson's disease which is damage to the substantia nigra and therein we understand that the basal ganglia is responsible for preventing that in normal people. So, if you look at chorea which is very sinuous

movements of the limbs we also realize that different disease within the same basal ganglia is responsible you know for preventing that.

So, ballismus is on the other extreme in which you know we got rapid movements uncontrolled these are non voluntary movements from the patient side. So, these are these are these are things which are suppressed by the basal ganglia from happen from happening in normal individuals.

Dystonia again the control of tone is lost to an extent that you know large areas of the body have very severe increases in tone for different time spans and that causes painful changes in changes in posture. So, I think I will show a little bit of the pathway so, as to make it a little more complete.

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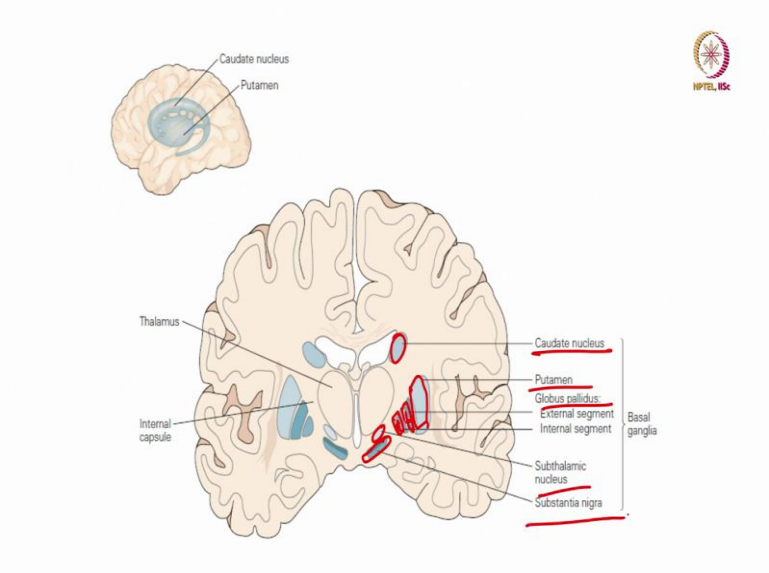

So, diagrammatic representation I think I explained this in my anatomy classes. So, please do check back if you have forgotten. Caudate nucleus, the putamen, globus pallidus, external is this one and internal is this one.

So, that is this is the globus pallidus, externa, interna putamen is outside and the caudate head is here, subthalamic nucleus substantia nigra is lower down and see these are this look disconnected, but they are very closely related hardly a millimetre away from each other and these are human names to a continuum of tissue which is there within the brain. So, please do remember that when you look at it.

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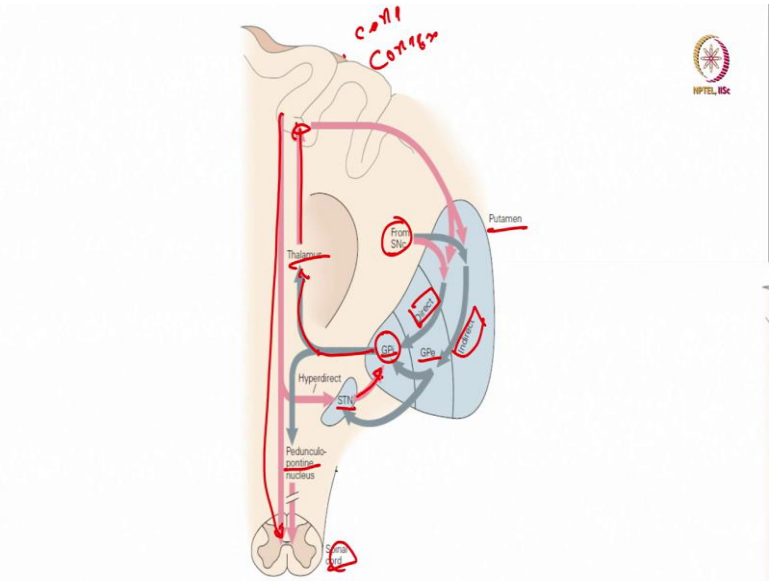

So, that is how these things look like the something a bit about the circuitry I am not going into deep parts of the circuitry because they are sort of medical topics and other than saying that a point A is connected to point B you do not have anymore information which is evident, point A connected to point B connected to point C and something A is positive and B is negative and so on and so forth.

So, I am not highlighting too much on the information. So, the network sort of starts from the substantia substantia nigra. So, you got two pathways you got direct pathway and the indirect pathway these are terminologies which if you are interested please go and read in greater detail.

So, there are inhibitory pathways and excitatory pathways. So, inhibitory is in red and this should be the stimulatory pathway. So, substantia nigra goes all the way to GPI then there is another pathway which goes from the putamen to the globus pallidus externa and goes to the substantia subthalamic nucleus.

Subthalamic nucleus in turn goes back into the globus pallidus interna. So, the output nucleus is the globus pallidus internal part of the globus pallidus that in turn sends in information to the thalamus and also to the pons from there on to the spinal cord. So, this mechanism these thalamus in turn relates on to the cortex.

The cortex in turn relates the information to the spinal cord. So, this is these are networks which are described these networks exist when the network gets disturbed in some fashion you have these various disease manifestations. So, as I told you these are various points within a graph and one of the edges of the graph gets cut you have a disease manifestation. I think that is a very simple way of explaining very complex disease processes.

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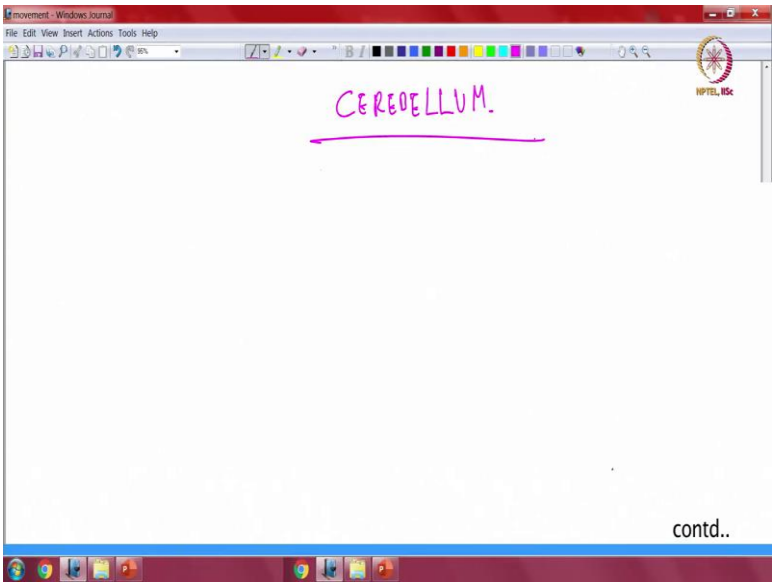

So, that is something about the basal ganglia, we proceed to a more interesting topic Cerebellum.