Neural Science for Engineers
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Lecture - 27
Monosynaptic Reflexes

Hi, today I will be starting exactly where I have stopped in my previous session, because there is a lot more development which needs to be brought in. So, in the previous session I highlighted the importance of the term called reflexes. Reflexes mean a lot of stuff, for the medical side of the story that is diseases and things like that. Reflexes are a method to check the integrity of the neural system.

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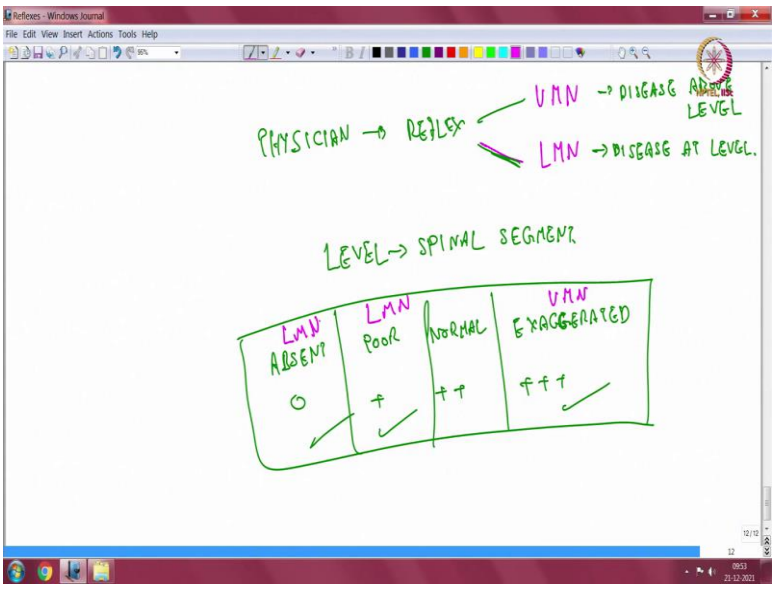

So, for a physician, anybody, neuro, non neuro, anybody, so a reflex gives information of something called as an UMN disease or LMN disease. So, UMN disease basically indicates disease above the level of enquiry. So, when I mean level, level means a particular spinal segment. LMN refers to disease at level. And that is only from analyzing the monosynaptic stretch reflexes.

In my introduction I spoke about the number of reflexes, monosynaptic and some polysynaptic reflexes are there and the outcome of testing like what I demonstrated in the video demonstration video. You know you find out those inferences and then you would actually classify. So, reflexes are classified as a 0, which is absent and just present which

is poor then which is double plus which is normal and 3 plus which is exaggerated. This is the medical side of the story.

So, medical side of the story you classified it you classified into various types and both this, this, this are abnormal. So, this is UMN, this should be LMN. So, physicians look at these values to evaluate whether it is LMN or UMN. We will go into it a greater detail in subsequent diagram.

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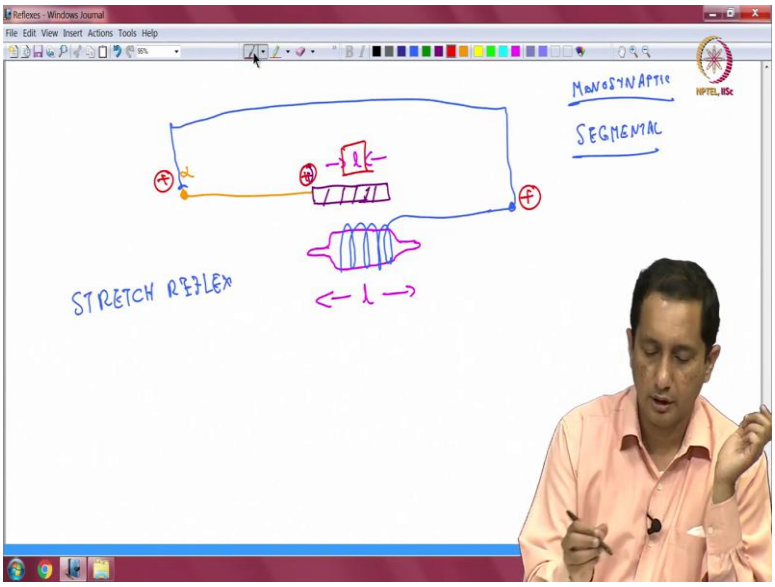

So, we will start with a single alpha motor neuron. So, alpha motor neuron ends up in skeletal muscle. So, that is skeletal muscle and this is when increase in this causes a decrease in length. So, that part is clear. Then we have got the muscle spindle. So, muscle spindle is like this.

So, what we saw during the stretch reflex is that the fibers which are from this one. So, we will draw those fibers. Go to a neuron and neuron goes and synapses with this same neuron.

So, it is a monosynapse, monosynapse is single synapse, monosynapse synaptic. So, monosynaptic is one single synapse. So, this is the only synapse in the circuit, and you should also remember that it is segmental. So, these things would for a given muscle fiber it is at a particular segment. We will analyze that at multiple segments because each

muscle gets innovated by multiple segments. So, it is not actually one segment which you are looking at when you evaluate a reflex, but it is at multiple levels.

So, this is how it works. So, when we look at the stretch reflect there is an increase in length. So, we increase the length. So, that causes activation of the neuron, that in turn stimulates this neuron and that in turn produces stimulation in the skeletal muscle and causes a decrease in length of the neuron.

So, this is the classic stretch reflex. Now, there are further players in this. So, what we will do is. So, we will move the stuff over here and so that was a stretch reflex. Now, we look at the generation of tone.

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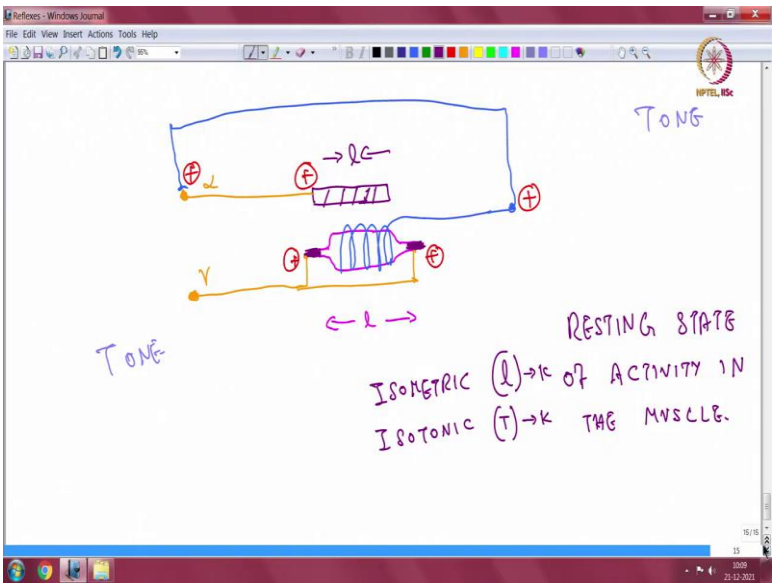

Same set of this one, but with an additional set of muscle fibers. This is innovated by something called as the gamma neuron. So, this is alpha, this is gamma. So, the gamma neuron supplies the end muscles. So, this is the picture. So, what happens with the phenomenon? How do we analyze tone? So, tone is like this. So, gamma neuron stimulates and that causes an increase in length.

Now, increase in length causes the spindle neuron to fire, that in turn causes alpha motor neuron to fire, that in turn causes skeletal muscle cell to fire and that in turn causes decrease in length. So, compared to this one, it is same right. So, stretch reflex and the

tone actually make a similar kind of actions. So, the phenomenon of tone is that is it is something like a resting state of activity in the muscle.

So, resting state of activity is these neurons have a baseline state of activity and that is responsible for state of activity of the muscle. And what is actually changing during muscle action is change in tone and change in length. Now, in this context I think we can start explaining something called as isometric and isotonic contraction.

So, how do I explain isotonic? Isometric contraction is the length of the muscle remains constant. In this tone is a constant. So, when length is a constant, the tone keeps on increasing. A simple example would be holding a glass which is getting filed with water.

So, you are holding a glass steady, somebody is filling or you are filling water into the glass and the load in the glass keeps on increasing because the glass is getting full. But you have to keep it in position because the water will otherwise spill.

So, as you are holding the glass steady, what happens is the muscle tone is increasing, but length remains constant. Only when length is constant will the glass hold steady. So, that is an example of isometric contraction. Isotonic contraction is lifting the same glass with the filled liquid to your mouth. So, the load on the muscle is the same, but the length has to decrease for the glass to be brought to your mouth.

So, that is the idea of isometric and isotonic contraction. So, the basis of which is the manipulation of these two hyper parameters by the nervous system. The generation of these hyper parameters is through the phenomenon which I have described earlier. Now, we will try to elaborate a little more into the circuit.

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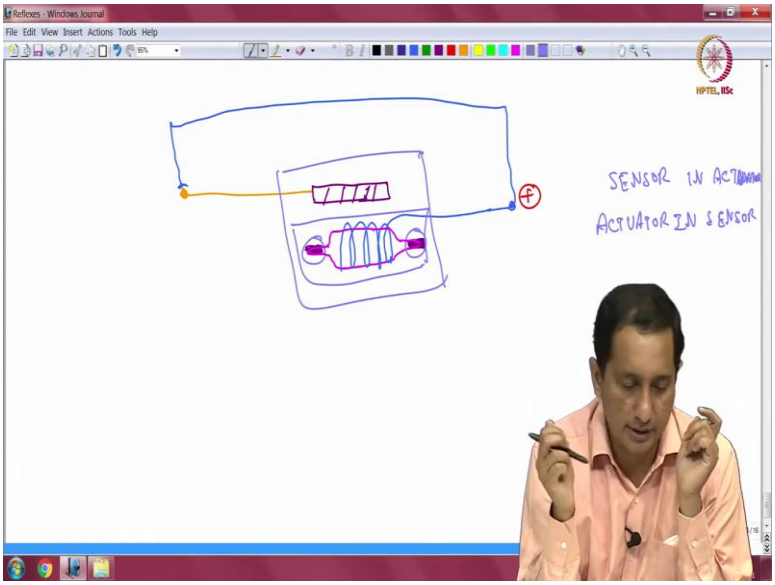

So, I would need to again paste my basic circuit. So, basic circuit pasted and what is now required is we need to connect some more stuff into this. So, circuit remains the same, the dynamics remains the same, but we will see as to how things happen when we add in little more dynamics to the whole issue.

So, again we draw muscles at the end of the spindle. Muscle fibers at the end; these are contractor elements, please remember that these are contractor mechanical actuators. And that was the basis of my telling basis of my telling of sensor in actuator, so sensor in actuator.

So, sensor in actuator is this complex this entire thing is in the muscle. Please remember that all these muscles do have these things. So, sensor in the actuator and actuator in sensor, so this is the actuator and that is present within this sensor complex.

Now, that is the beauty of it, and we will elaborate this in greater detail because I feel this is a very beautiful mechanism and it has so many concepts. I think many of you from who are not student engineers would be able to recognize that these are basic mechanisms and they may reflect existing engineering practices.

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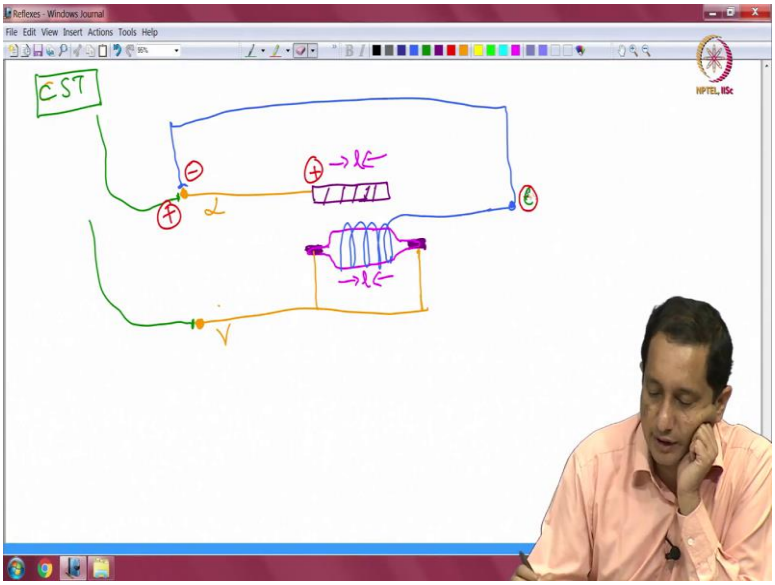

So, this is alpha motor neuron. So, this is alpha we need gamma, gamma motor neuron. So, this stimulates. So, this is gamma motor neuron. Now, we have discussed the corticospinal tract. I showed how the corticospinal tract is the tract within the spinal cord as I showed you in one of the previous sessions.

So, corticospinal tract goes up to the medulla, crosses in the pyramid. So, that is the place where the crossing over happens. Upper part, a place where it is distinctly seen is the mid brain peduncles. Peduncle is that anterior swelling in the mid brain and from thereon you can trace it back to the motor cortex.

So, the motor cortex contains the giant cells or beds which are the specific cells giving rise to this fiber tracts. All down from the motor cortex it comes down and then goes through the spinal cord anterior part of the spinal cord and reaches the anterior horn cell.

So, the alpha motor neuron is also called as the anterior horn cell. Corticospinal tract, so from there up you get this stimulating this one. So, we will check the dynamics as to what happens with the circuit.

So, corticospinal tract stimulates. So, you are looking at stimulation here. I think I should draw it the other way around. So, that is not to confuse with the spindle output. So, this is plus, this is plus that causes a decrease in length. Now, the decrease in length actually causes decrease in stimulation.

Now, decrease in stimulation causes a decrease and that is about it. So, this is what would happen if in case you just had a corticospinal tract which is just sending stimulus. The action does not get sustained. So, on the contrary what actually happens is there are pathways which lead directly to the gamma motor neurons. So, when this cycle is happening, there is a parallel activation which is happening over here. So, and we will see how that makes it very different for the entire circuit.

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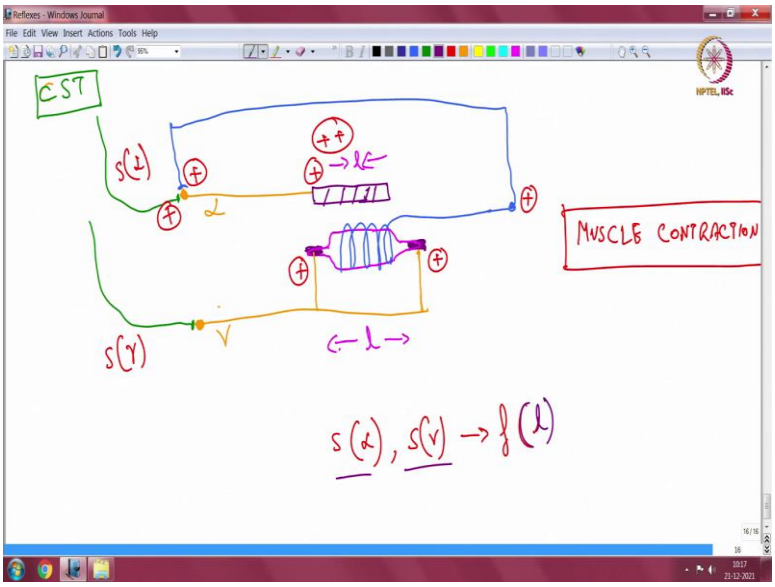

So, what happens when you have simultaneous gamma activation is gamma activation causes activation of both the end this one. So, in the sense that there is no decrease in length here, it causes increase in length here, increase in length here. And the increase in length causes an increase in activation and the neuron actually stimulates this alpha motor neuron and then we are looking at plus plus.

So, plus plus in the previous slides I told you is the regular way in which actions actually happen and so that is how you have muscle contraction which is sustained. Now, for the people who are computationally inclined you would notice that this gives a very beautiful method of control. So, you can change the signal of the gamma versus the signal of the alpha and control the output. So, signal alpha, signal of gamma can act to the function change of the length of the skeletal muscle.

So, I do not know the notation for showing difference between two signals and so that is the reason I am showing this. So, these are very elegant mechanisms by which the circuit

is managed. So, these are basic level. I have just so far discussed only the monosynaptic reflex and how the upper centers are involved in controlling this reflex.

So, what we will do is we will copy this entire stuff, try to analyse what happens to this network in busy states. So, in a busy state we are looking at various kinds of breaks. So, we will try to emulate what those breaks are and how interpretations are made on patients by this one single monosynaptic reflex.

So, that is the idea. So, construct the busy states in this network and that is the reason I am going to change. So, what we do during the tendon reflex elicitation is what I had shown in the video.

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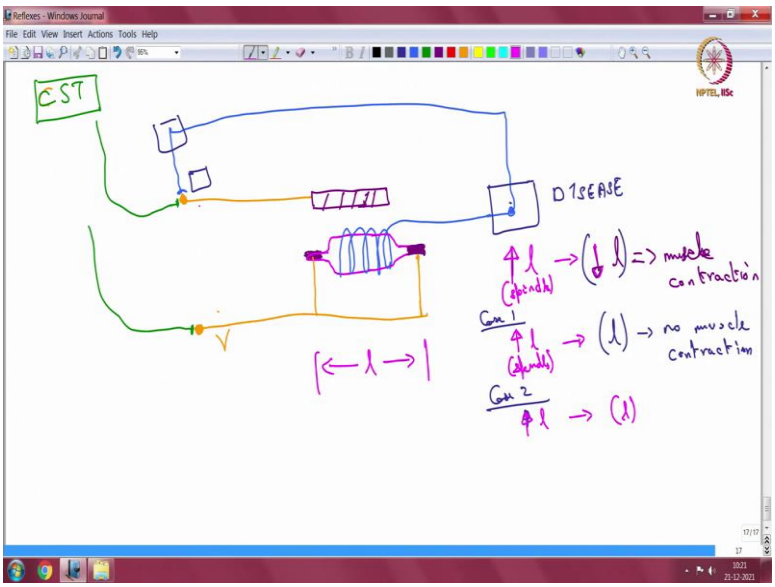

So, we are increasing length. So, that is the length which increases over here. So, increase in length and that results in decreasing in fiber length. So, that is contraction. So, decrease in length which implies muscle contraction. So, increase in length of the spindle causes a decrease in length of the muscle and that is the stretch reflex.

So, what happens if we have diseases. So, generally we look at diseases in the spinal cord, so anywhere along this pathway. So, we imagine that there is a disease somewhere over here what happens? So, we put a disease here which is box and so disease. So, when there is a disease over there what happens? So, we do the same increase in length for the spindle, case 1 it is.

So, what happens with disease? So, when there is an increase in length which still continues to be there this thing there is no activity within this cell. So, this cell does not produce an activity, so there is no activity over here. So, when there is no activity over here length of this remains same. So, that indicates that there is a no muscle contraction, and what no muscle contraction is indicative that there is a disease in somewhere in this circuit.

So, where would the circuit be? It can be here, it can be here, it can also, ok we will do that in subsequent cases. So, we will look at case 2. Again, increase in length of the spindle, this causes no change in length because logic remains the same. So, you have anywhere in the, this is in the neuron, this is in the tract somewhere, the logic remains the same.

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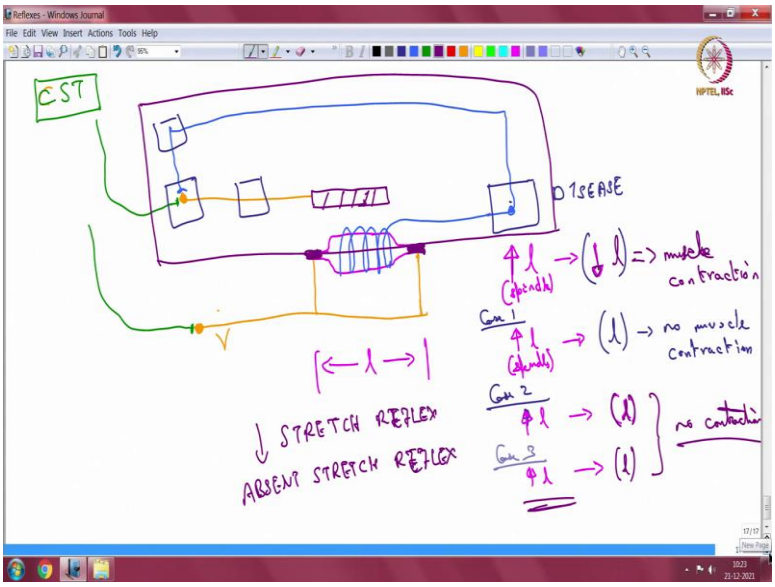

So, we will check the third case, case number 3; disease in the motor neuron. So, disease in the motor neuron and disease over here. So, in that case what happens? Increase in length, which is the same produces no change in length, so no contraction.

So, all these 3 cases, so wherever the disease is within this part of the story, this part of the story you are having no contraction when there is an increase in length. So, that is either a decrease stretch reflex or absent. So, this is this is the mechanism of the decrease stretch reflex in this set of cases.

Now, we look at the other kind of diseases. Somewhere along the corticospinal tract if you have a disease.

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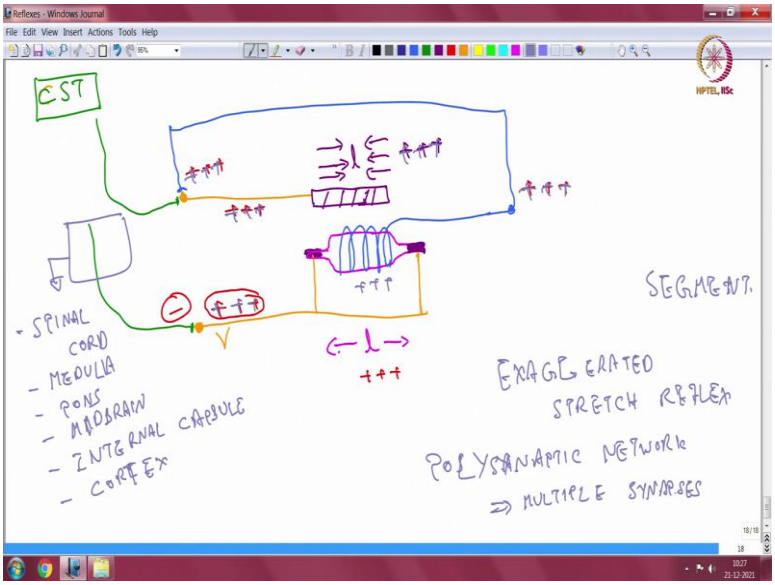

So, corticospinal tract actually decreases the signal over here. But that actually increases signal over here ok. That produces increase in the intermediary neuron. That increases signal to the alpha motor neuron that causes increase in the signal here and that causes decrease in the length basically increased.

So, this is a disease process in which you have a break in the spinal cord somewhere up in the medulla, pons, mid brain, internal capsule and the cortex. So, this refers to all of this. So, when you have that phenomenon the control of the brain on this particular level segment. So, this is a segment. So, control of the segment is lost by the higher center. So, what that means is the segment becomes autonomous in functioning, that basically indicates that these things get exaggerated.

So, that causes increase in stimulus, stimulus increased, increased stimulus, increased stimulus, increased stimulus. So, so reiterating, so, this is the mechanism of an exaggerated stretch reflex. So, we will stop at this. I have already introduced the concept of polysynapses.

So, polysynaptic network where there are multiple synapses. So, multiple synapses are there within the network and inevitably even though we say it as monosynaptic you can imagine that it is a parallel circuit.

So, there is one circuit which is between the skeletal muscle cell and the alpha neuron alpha motor neuron. There is a parallel sensory pathway which is through the spindle going back into the alpha motor neuron, the synapse remains one, but the circuits are different. Circuit is one is into the motor cell the other one is from the parallel cell that is the spindle cell.

The gamma motor neuron is another parallel setup which is in conjunction with these two systems and all these three things put together is responsible for tone, is responsible for maintenance of muscle activity and what the higher centers do is basically tweak these two parameters.

One is the tone the other one is the length. So, there are mechanisms by which you can change or tweak the tone. So, tweaking the tone you reduce the tone by increasing corticospinal activity which is the amount of signals coming from the head into the muscles.

Decreasing tone is increasing activity in the corticospinal tract to the gamma neuron within the muscle fibres and that in turn causes decreasing in the tone. The alpha motor neuron basically is responsible for contracting against a given tone. So, you have a specific baseline tone sitting in the muscle and when you get alpha activity you have a positive change in length. So, this is the mechanism by which you can control these two parameters and it is a very beautiful integral mechanism.

See you do not have two different sets of systems to produce these two varied activities. Isometric contraction is constant length you can actually hike up the tone without changing the length and it is obvious see for anybody who has held a glass you can appreciate; maybe more than I think glass any kind of fine art painting in which you need to you know you got to precisely mark points on a paper or any worksheet you and appreciate the fact how much of how much of stability is required for that.

So, the groundwork of this mechanism is in is based on the stretch reflex. The stretch reflex is used by physicians to evaluate patients and that is another important reason why

it is necessary to be study. So, we will in the next session elaborate a little more on this and then try to derive further mechanisms. So, far we have discussed stretch reflex, the principles of tone, the influence of the corticospinal tract on the higher centers on these lower centers.

In the bargain we have also understood what a segment of this panel cord means. What a supra segment problem leads to, that is it is called a UMN in medical terminology upper motor neuron. Upper motor neuron is any of these things spinal cord, medulla points, mid brain, internal capsule or the cortex. Lower motor neuron refers to the activity at that particular spinal segment, could include the alpha motor neuron, its output to the skeletal muscle per se. Diseases involving the nerve from the other direction.

So, the sensory nerve also is in the same nerve complex, and you can have decision specifically affecting that. So, all of these things are responsible for maintaining. So, it is a very elegant method of evaluating nervous system function.

So, you just tap somebody's tendons you get a lot of information on overall functioning of the brain spinal cord and disease. So, to give you an example, patients who have strokes, have UMN disease will have exaggerated stretch reflexes. Patients who have muscle disease have lower motor neuron kind of problems and that causes decrease stretch reflexes.

And another example of low motor neuron disease is polio. So, polio is degeneration in the anterior horn cell that is the neuron and that causes a decrease in the output of the muscle cell which should reflect in a neurological examination as decrease in tone and a decrease in the stretch reflex. So, tone is intricately connected with the principle of eliciting the response, so they go together.

So, high tone would almost always reflect high reflex activity and low tone would reflect a lower reflex activity. So, that is the clinical correlation. We stop it here and then continue with poly synaptic reflexes and some more of these circuits.