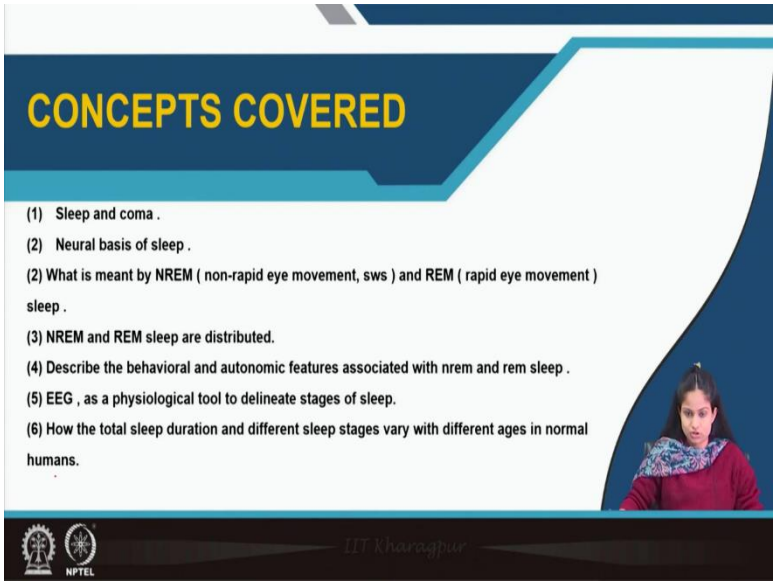
Basics of Mental Health & Clinical Psychiatry
Professor. Doctor Arijita Banerjee
Indian Institute of Technology, Kharagpur
Lecture 20
Physiology of Sleep

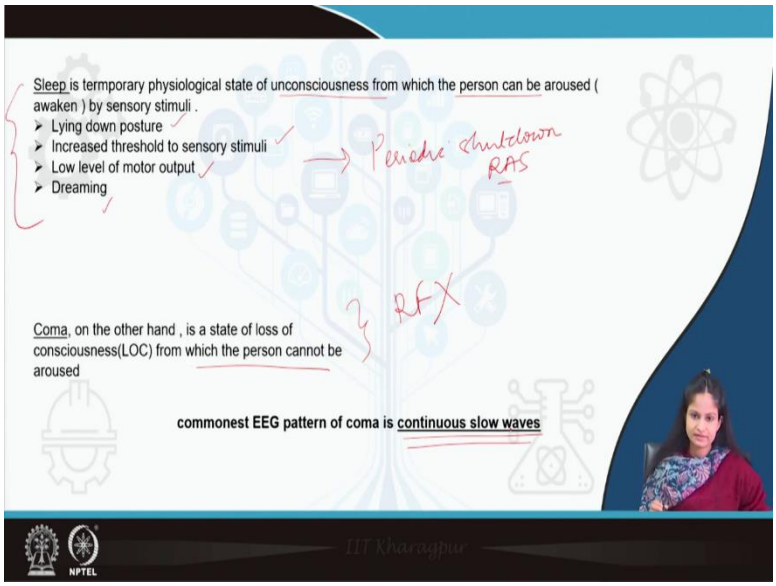
Hello everyone. So, today we will start our next topic that is Physiology of Sleep.

(Refer Slide Time: 00:33)



Now, the concepts we will cover in this topic, sleep and what do you understand by sleep and coma? What is a neural basis of sleep? What are the various types of sleep, that is, REM sleep and non-rapid eye movement sleep. And how they are distributed in night sleep. What are the various behavioral and autonomic features we get associated with this type of sleep? And how EEG is physiological tool is used to delineate various stages of sleep? And how the total sleep duration and different sleep stages vary with age?

(Refer Slide Time: 01:11)



So, what do you understand by sleep? Now it has been already said before that whenever our reticular activating system or the reticular formation in our body is active, the person is awake because reticular formation keeps the person awake. It is mainly (re) responsible for arousal state. So, whenever there is a periodic shutdown of this reticular activating system or reticular formation, this periodic shutdown means there will be periodic shutdown, the word periodic is important over here because if it is complete shutdown, then the person will go into coma.

So, periodic shutdown means there is alternate periods of waking and sleep. So, whenever there is periodic shutdown of reticular activating system, or reticular formation occurs in our body with the various circadian rhythm that is light and dark cycle and other the various parts of the brain, at that time, we get into sleep. So, sleep is a temporary physiological state of unconsciousness from which the person can be aroused.

And there are various speeches of sleep, which we must remember, that is a lying down posture. Increased threshold to sensory stimuli. Increased threshold to sensory stimuli means whenever you are sleeping, if you are hearing any sound, you do not get awaken very easily. Then, when you were not sleeping. When you were alert, when you were awake, you react to that stimuli much faster. So, the increased threshold to sensory stimuli occurs in case of sleeping.

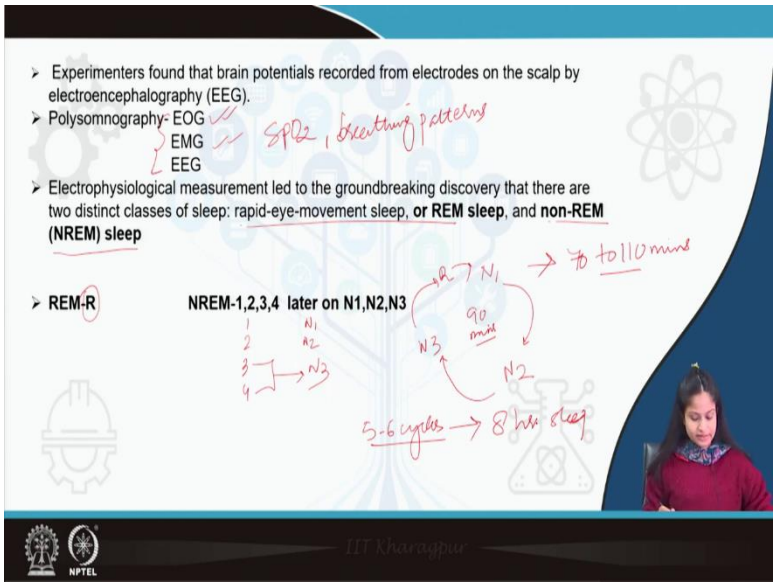
Low level of motor output, obviously you do not talk, you do not run, you do not eat during sleeping. You, the level of motor activity gets decreased to a large extent and unique behavior

of dreaming. Now, dreaming is seen in both the types of sleep, which we will discuss. In one type of sleep, you could recall your dreams, whatever you have seen in your dreams. In another type of sleep, you just have some vague thoughts, you are not able to recall. So, that is a unique behavior of dreaming.

Now, all these things occurs in case of coma also, because here there is a periodic shutdown of reticular formation or reticular activating system. But in case of coma, there is not periodic shutdown, but reticular formation is definitely not acting, that is a complex shutdown. So, this features momentarily, if the person is in coma, you will not be able to distinguish whether he is into coma or sleep. The only thing is, the person cannot be aroused from coma, but you can awake a person from sleep.

The second thing is the commonest EEG pattern, because in previous lecture you have seen the EEG, the Electroencephalography recording shows various mixed pattern of waves in EEG. The various stages of sleep have got various waves. There is alpha, there are beta waves, there are delta waves. There are other types of waves also. So, mixed pattern of waves you see in EEG. But in case of coma, the commonest pattern of waves you see is continuous slow waves. So, continuous slow waves you see in case of EEG.

(Refer Slide Time: 04:47)



Now, with various experiments and various instruments, whether it is EEG or other like, Polysomnography. Polysomnography is consists of Electroencephalography is one, besides, it has got Electrooculography, that is EOG. And EMG is when the muscle activity you were

taking. Electrooculography, EOG means when you are taking the activity of the eye movements, eyeball movements and EMG is the muscle activity and EEG of course.

This is Polysomnography. This is the study which will determine or help to stage the various types of sleep. And besides also we measure SPO2 and various breathing patterns over here in various types of sleep. Now, electrophysiological measurements has given rise to usually two types of sleep. The one is rapid eye movement sleep, from the name REM - Rapid Eye Movement sleep. And the other one is non rapid eye movement sleep.

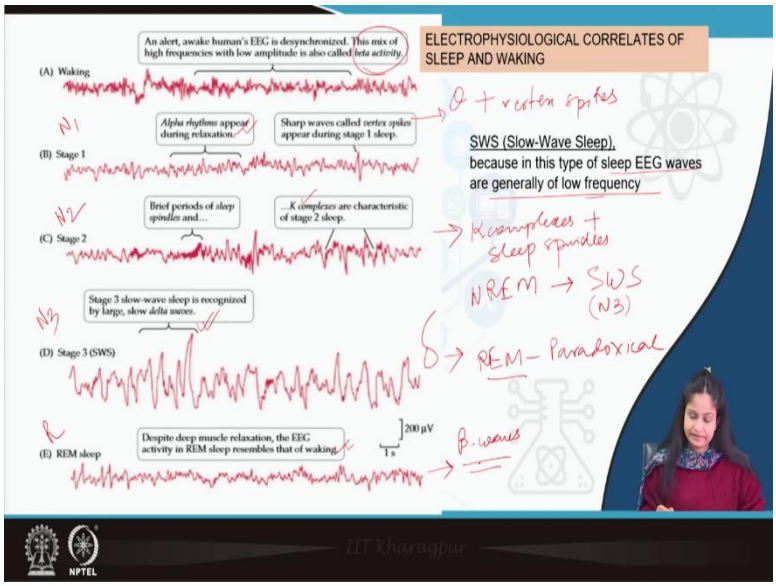
Usually, rapid eye movement sleep is denoted by R and non-rapid eye movement sleep previously used to be denoted as, into four stages, like Stage 1, Stage 2, Stage 3, and Stage 3, and Stage 4. But now, the nomenclature has been changed to N1, N2, and N3. So, stage 1, 2, 3, and 4 was the previous nomenclature. Now we have N1, N2, and this 3 and 4 has been clubbed as N3, as the various stages of non-rapid eye movement sleep, any REM sleep. That is three stages we have.

Now, what is most important over here, a person when he or she goes into sleep, they go into sleep by going into one by one stage. For example, the person will enter into N1 sleep, N1 stage. Then the person will go into N2 stage. Then the person will go into N3 stage, then the person will go into R stage. And this cycle continues in this way. So, in the first cycle of the sleep, this will happen from N1 to N2, then N3, and then R.

But this cycle is not maintained after the first cycle. There can be opposite entry of into any stages. That means, from the second cycle the person can enter into N2 stage directly, or the person can enter from N1 to N3 stage. Or there can be omission of N3 stage. So, there can be any changes in between this cycle in the various stages of sleep that can occur after the first cycle. So, the first cycle will constitute and N1, N2, then N3, and then R.

This cycle will get repeated around 5 to 6 times to complete your 8 hours of sleep generally. One cycle usually averages for around, the duration range is 70 to 110 minutes. But average we take of 90 minutes. So, one sleep cycle is taking 90 minutes. And suppose if you take, you are having 8 hours of sleep, so that means this cycles will go around 5 to 6 cycles. So, there will be 5 to 6 cycles in an 8 hour sleep. And as I told you, the first cycle will have this proper chronological order from N1, N2, N3, and R, but later on this order may not be followed in the other cycles.

(Refer Slide Time: 09:00)



So, this has already been discussed a bit in the last chapter of EEG recording; the electrophysiological correlates of the sleep. Initially when the person is awake, there will beta activity. When the person is then relaxing and closing the eyes, there will be alpha activity. After that, if the person is going into drowsiness, then there will be theta activity. Now this theta activity can be composed with certain spikes known as vertex spikes.

So, Stage 1 sleep can have theta waves, plus V, or vertex spikes. So, this we are talking about various stages of sleep and the electrical activity. Now, the person will enter into Stage 2, or the N2 stage. This is N1, this is N2, and Stage 3 is the N3. And REM is the R. So, when the person is entering into the N2 stage, there will be brief periods of sleep spindles and also K complex. So, stage two is very much significant with K's complexes and sleep spindles.

So, see, if anybody ask you sleep spindles are seen in which stage of sleep, it seen in the N2 or the Stage 2. Then it will move into the deep sleep or known as slow wave sleep. That is mainly characterized with delta waves. You can see the delta waves are seen in case of Stage 3 or the N3. Now, this slow wave sleep is because it has got very low frequency. The EEG waves are seen here in deep sleep are having very low frequency. So, that is why the name is given slow wave sleep. So, SWS is the slow wave sleep, which is typically of N3 stage because of the delta waves.

And then we come to the R sleep or the rapid eye movement sleep. Now, rapid eye movement sleep is again, despite the muscle is relaxing. The EEG activity in rapid eye movement or REM

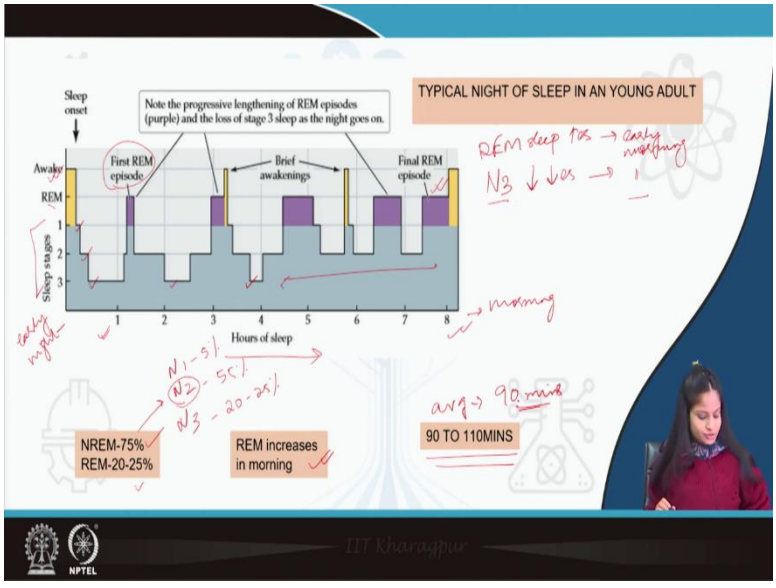
sleep is showing as if the person is awake. Now, when the person is awake, I told you, when the person is awake, the EEG activity or the electrical recording will be of beta waves. So, here in R sleep or the REM sleep, we get beta like waves. So, that is why REM sleep is also known as paradoxical sleep.

The non-REM sleep that is NREM sleep is also known as slow wave sleep because of the slow wave, the low frequency of the delta waves. It is mainly class, characteristics of N3 stage. But REM sleep is known as the paradoxical sleep. Paradoxical sleep, paradoxical means whatever you are expecting and whatever you are observing are totally contradictory to each other.

Now, in REM sleep, the person is sleeping, the muscles are all relaxed, there is deep relaxation of the muscles and the person is into the sleep. But if you are recording the EEG activity, the electrical activity, it is showing as if the person is awake, there is beta waves. So, these are two contradictory features. The person is sleeping, but the record I am getting from EEG is as if the person is awake.

So, that is why this is rapid eye movement sleep or R sleep, it is seen during the last phase of the sleep that is during the morning. So, this is known as paradoxical sleep, non-REM sleep, and the REM sleep.

(Refer Slide Time: 12:59)



Now we will move on to this various stages of sleep, which happens in our one night. One night sleep, what happens in a young adult? So, if we start, this is the awakening stage, then this is

the REM, and these are the various stages, 1, 2, 3. So, as you can see, this is the hours of sleep, the 8 hour sleep duration is there. This is the starting of sleep onset, and this is the end of sleep. That means this is towards the morning and this is early night.

So, you can see during the early night, the person is having less amount of REM sleep or REM episodes, but as the person is moving towards the morning, that means towards the 8-hour sleep, this REM or the rapid eye movement sleep increases. So, the first point is REM sleep duration usually increases in the early morning. You know, early morning sleep is very, we call is very deep, it is very difficult to awake the person from early morning sleep, then the early night sleep.

Then we have various stages like N1, N2, and N3. So, you can see this is N3, N2 and N1. So, as the sleep progresses toward the morning, I mean towards the 8-hour duration, you can see the Stage 3 or N3, you can see N3 is present here, N3 is present here, N3 is present here. But there is no N3 in the rest 4-hour cycle. So, N3 decreases towards early morning.

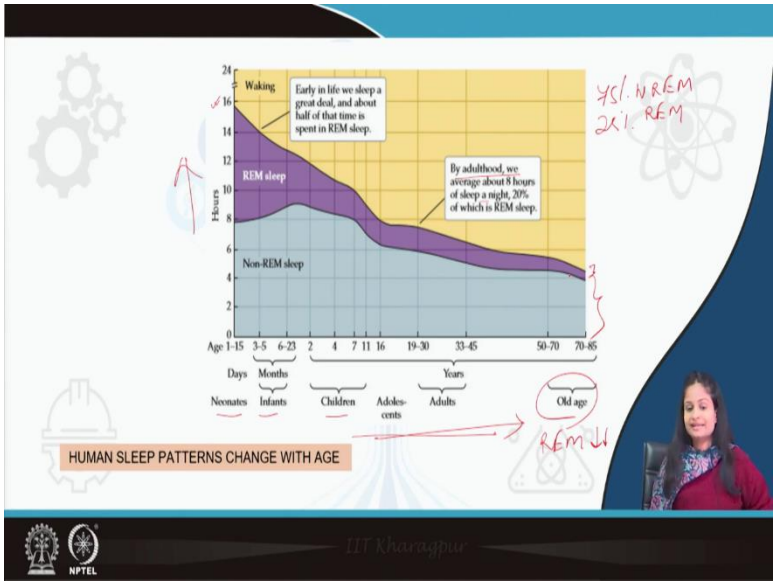
So, there is two things we have to remember because I told you the rest of the cycle, it may not happen chronologically. Only the first cycle is very important. The first cycle, the stages happen chronologically from N1, N2, N3, and then R. The rest of the cycles, they do not follow that order. So, REM sleep increases during the morning and N3 stage of the sleep decreases during the early morning.

Besides this, the non-REM sleep accounts around 75 percent of our sleep. Whenever we have this 8-hour duration of sleep, we see, it has been noted from experiments that 75 percent of our sleep is non-REM, NREM, which includes various stages. And 20 percent to 25 percent of the sleep is REM. That is rapid eye movement sleep. And among this non-REM and REM, the 75 percent of this, we have N1, N2, and N3. N1 constitutes only 5 percent. N2 constitutes around 55 percent, and N3 constitutes around 20 percent to 25 percent.

As I told you, N3 decreases towards the early morning. So, N2 is the maximum amount of, if the question is asked, which stage is seen maximum in the sleep, that is N2, 55 percent of the sleep is mainly because of this N2 stage where we get sleep spindles and K complexes. Now, REM sleep increases during the morning, and N3 sleep decreases during the early morning. And as I told you, the duration is around 70 to 110 minutes, but the average duration of one

cycle is 90 minutes. In this way, it completes five to six cycles in case of 8 hours, 7 to 8 hour of sleep.

(Refer Slide Time: 16:58)

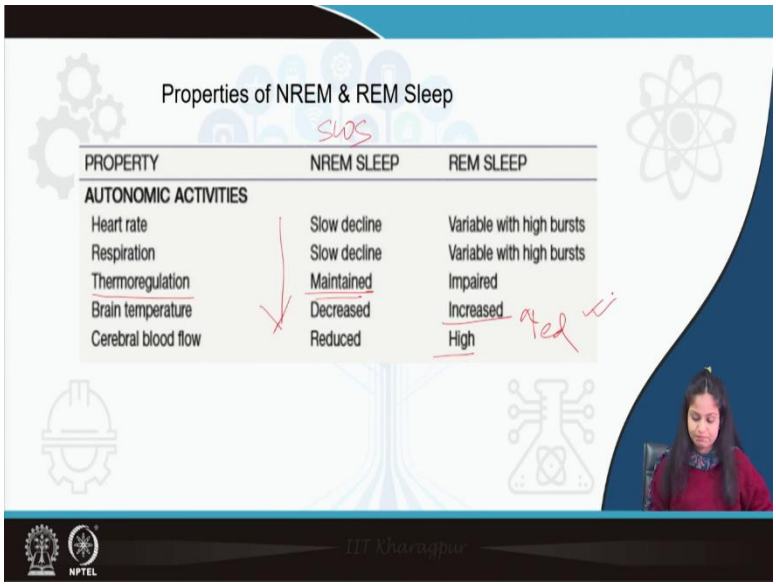


So, these are the stages arranged. Now coming to the sleep, human sleep, how it affects various age group. Now, you know the children forget about children, infants, they sleep a lot, hardly 4 to 5 hours they are awake, the infants. So, this is the neonates, infants, children, you can see the ages progressing and these are the hours of sleep. So, you can see, in a 24 hours in a day, almost 16 hours, a neonate or infant is sleeping.

And this 16 hours is constituting 50 percent of the REM sleep and 50 percent of the NREM sleep. And only 7 to 8 hours they are awake. Just the opposite, what happens in case of adult, 7 to 8 hours, we are asleep and the rest of the period we are awake. So, as the age progresses, you can see by adulthood about 8 hours of sleep a night occurs, and among that I told you, 75 percent is NREM sleep and 25 percent is REM sleep. This happens in adult.

And in case of old age, this REM sleep also decreases. Old persons, if you just observe, they have a tendency to awake very early in the morning as compared to us or the adults. Why? Because the REM sleep decreases. You can see the sleep any end that anywhere decreases the total duration of the sleep also, they do not sleep for 7 to 8 hours. They usually sleep for 5 to 6 hours. And among that, the REM sleep decreases very much in case of old age. That is why there is a tendency of easily awakening in case of old age.

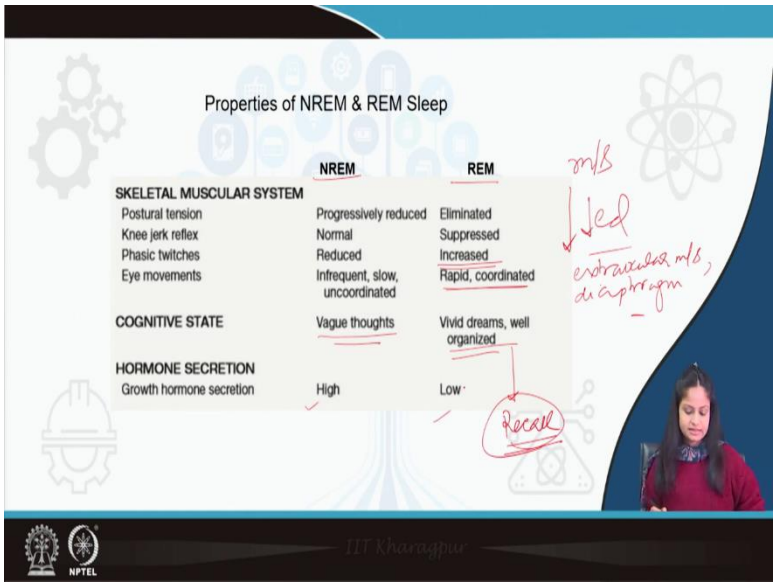
(Refer Slide Time: 18:52)



So, the properties of the two types of sleep we will see. The autonomic activities. Every autonomic activity decreases in case of NREM sleep, except the body temperature, which usually remain normal. The body thermoregulation that is maintained. Otherwise, the heart rate, respiratory rate, cerebral blood flow and the brain temperature, everything decreases during the slow wave sleep, NREM sleep or slow wave sleep.

But what happens in case of REM sleep? In REM sleep, there is increased brain temperature and increased cerebral blood flow. Obviously, the brain is active, there is movement of the eyeball and the brain is active and that is why you could see the EEG recording of beta waves. So, that is why there is increased brain temperature and increased cerebral blood flow. The thermoregulation is usually seen to be impaired.

(Refer Slide Time: 20:00)

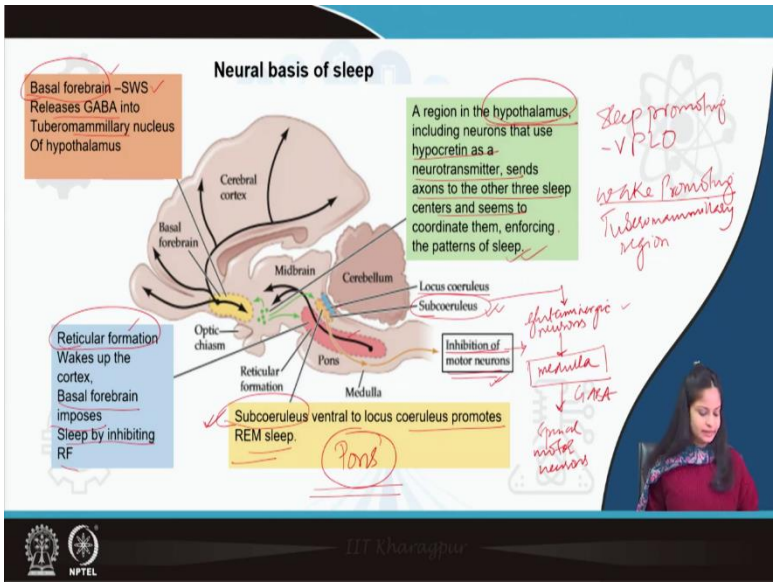


And what are the skeletal muscular system or the motor system? In the motor system in case of NREM and REM sleep, what you have to remember is in case of REM sleep, all the muscular activities are decreased. Very much decreased muscular activity, except there are phasic twitches. The phasic twitches are important and there is movement of the eyeball. So, eye movements are rapid, which are coordinated.

All the muscle activities are decreased, except your ocular extraocular muscles, because there is rapid and coordinated eye movements and diaphragm. Because if respiratory diaphragm, the respiratory muscle, main respiratory muscle, so if the diaphragm activity is decreased, obviously the person will go into coma, or the person will go into death. So, there will be respiratory arrest in the REM sleep. So, that is why diaphragm activity is not decreased. So, diaphragm activity and the extraocular muscle activities are not decreased, rather eye movements become rapid, but all other muscular activities are decreased.

And cognitive state, there are vague thoughts dreaming, if a person is dreaming in slow wave sleep, they will not be able to recall. So, recalling of the dream is present in REM sleep. There is a saying that if you dream in the early morning, it becomes true. Actually, early morning sleep is REM sleep and that is the only dream you remember. The other dreams anywhere you will not be remembering. So, you could recall that dream in the REM sleep only. The hormone function is high and it is low in case of REM sleep.

(Refer Slide Time: 21:59)



The neural basis of sleep. What is a neural basis of, till now we have seen what are the stages of sleep, how a person sleeps, how it is decreased or increased as per the age. Now why the sleep occurs? The four important centers of brain in our central nervous system are very important for this generation of this sleep. The first important is basal forebrain. The second important is brainstem or the reticular formation. Then we have Pons or the pontine region. And then we have hypothalamus.

Now before going into this, in hypothalamus, I had told you there are two region. The one is sleep promoting, the center which promotes sleep, that is VPLO. And the another one is wake promoting region, that is tuberomammillary region. One is in the anterior, and the other one is the in the posterior hypothalamus, so the tuberomammillary region.

So, sleep promoting region is present in the hypothalamus, VPLO nucleus, and the wake promoting, that is the tuberomammillary region. So, there is a balance of this action of this two nucleus in the hypothalamus, along with the other centers. So, what does basal forebrain do? Slow wave sleep which usually seen in case of basal forebrain, the basal forebrain releases GABA.

The GABA is the main inhibitory neurotransmitter and this is released from the basal forebrain into the tuberomammillary nucleus. I told you tuberomammillary nucleus is the wake promoting center. So, the wake promoting to enhance sleep or induce sleep, I have to inhibit my

wake promoting center. So, how it will be inhibited? By inhibitor neurotransmitter and the neurotransmitter is GABA.

And from where GABA is secreted, GABA is secreted from the basal forebrain. So, any lesions which is occurring or if any malfunction is occurring in this basal forebrain, the person usually suffers from insomnia. There is lack of sleep because the GABA is not getting released to inhibit the tuberomammillary region or the wake promoting region.

The second is the brainstem or the reticular formation. As I told you, reticular formation in our body keeps us awake. That is arousal. That means the reticular formation in our body during sleep has to be inhibited. That is also done by basal forebrain. Basal forebrain imposes sleep by inhibiting reticular formation.

The third point is Pons. We know that REM sleep is usually originated from Pontine center. We have ponto-reticular fibers and the ponto-geniculate fibers that give rises to REM sleep. But where is that exact location of the origin of sleep has been discovered. So, that is the location which lies ventral to the locus coeruleus. So, this is the Pons, this is the locus coeruleus. And you can see ventral to the locus coeruleus is subcoeruleus nucleus.

The subcoeruleus nucleus is the origin or which promotes REM sleep. Now how the subcoeruleus nucleus will promote this REM sleep? Here mainly in the pontine region we have cholinergic neurons and we have seen if we give cholinergic neuron agonist, I mean cholinergic agonist, or if we stimulate the pontine center, then the person gets sleep or the prolongation of REM sleep occurs.

So, from that point, the scientists have come to the discovery that there has to be some pinpoint center in the pontine region or the Pons, which gives rights to this REM sleep. And that pinpoint center is subcoeruleus nuclears. Now what does subcoeruleus nuclears do? It inhibits the motor neurons. How it inhibits the motor neurons? It inhibits the motor neurons with the help of the glutamatergic neurons.

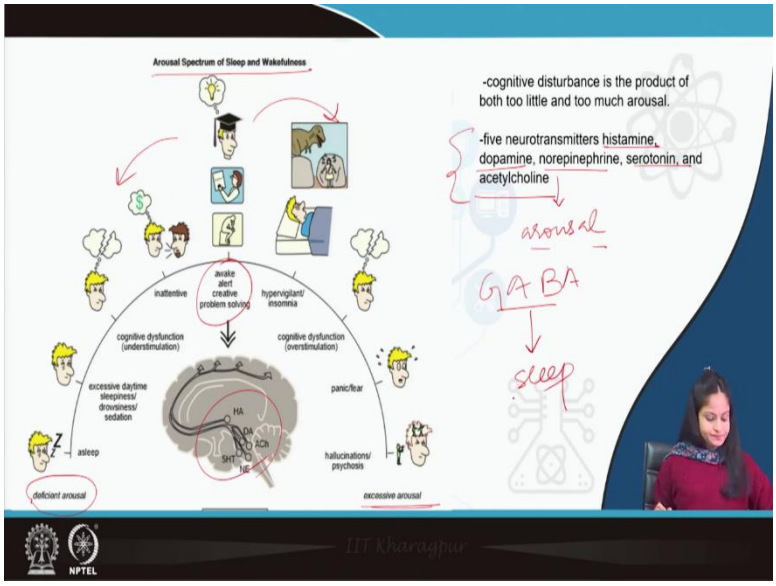
The glutamatergic neurons are secreted from the subcellular nucleus. The glutamine neurons are secreted at the level of medulla and this will stimulate the medulla to inhibit the spinal motor neurons. Obviously, with the help of inhibitory neurotransmitter, either GABA or

glycine. So, subcoeruleus nucleus, they secrets glutamatergic neurons and glutamatergic neurons stimulate the medulla.

And at the level of medulla, the neurons will be secreting inhibitory neurotransmitter and will be acting on the spinal motor neurons, thus inhibiting them. So, what will happen, the muscles in our body will get not only relaxed, but placid. When a person is having REM sleep during the morning, when the person is actually dreaming, you will see it is very difficult to awake that person. Even the person tries to get awake also, the person is not able to get aroused or awake from the dream or the sleep because the tone of the muscles gets placid.

And this occurs because of the inhibition of the motor neurons with the help of subcoeruleus nucleus. And finally, when this all organs, basal forebrain, the pontine region, that is a subcoeruleus nucleus and the reticular formation, these are all working adjunct with the hypothalamus. Hypothalamus will be secreting the lateral hypothalamus, particularly orexins or hypocretin as a neurotransmitter, which binds or which sends exons to other three centers and coordinate their actions, and enforces the various patterns of sleep.

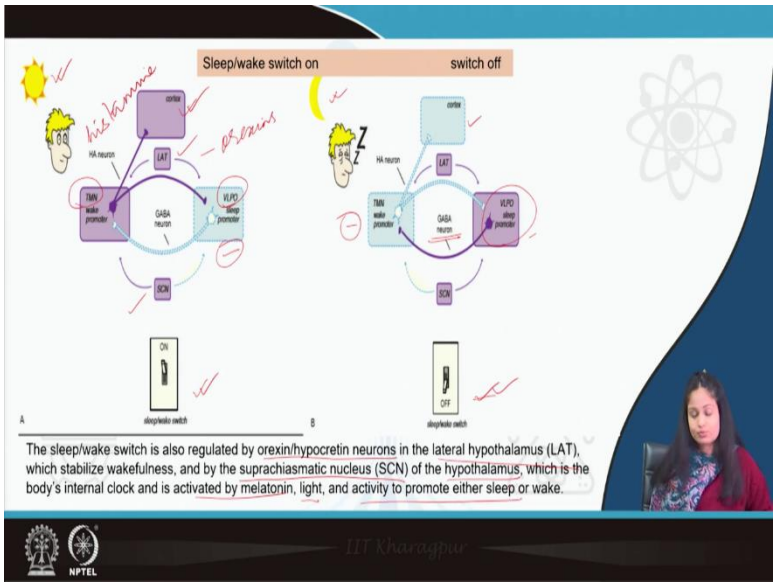
(Refer Slide Time: 28:40)



So, we can see this spectrum of sleep, wake cycle sleep and wakefulness. You can see this is the normal where the person is awake. The person is solving various problems. The person is normal. Now this portion is, from my side, if I go to this side, there is deficient arousal. Deficient arousal means the person is going into sleep. And from here, this side if we go, there is excessive arousal. That means the person is not having sleep or insomnia.

So, cognitive dysfunction happens in both the cases. If you are having less sleep or whether you are having too much sleep, you will get cognitive dysfunction. You can see the various neurotransmitters responsible for keeping you awake, histamine, dopamine, norepinephrine, serotonin and acetylcholine. These are the neurotransmitter which usually helpful for arousal or keeping you awake. An inhibitory neurotransmitter is mainly the GABA which induces sleep.

(Refer Slide Time: 29:54)



Now we will see the sleep/wake, how it is sleep/wake cycle or the switch on or on mechanism. Now in case of switch on mechanism, suppose you can see, there is sunlight, the person is awake. Now this sleep/wake cycle occurs in aspect with the circadian rhythm. Circadian rhythm, I also discussed in the hypothalamus the suprachiasmatic nucleus of hypothalamus, they play a very important role in entranment of your 24 hours cycle.

So, this suprachiasmatic nucleus, this acts with the help of melatonin hormone as well as the light input, the external cues it gets. That is the light input in this case. So, that will activate various retino hypothalamic fibers and that will activate your pineal gland and cause the entranment of 24 hours cycle. Now what happens, this is the tuberomammillary nucleus, this is the sleep promoting region that is the interior nucleus or the VLPO nucleus of the hypothalamus.

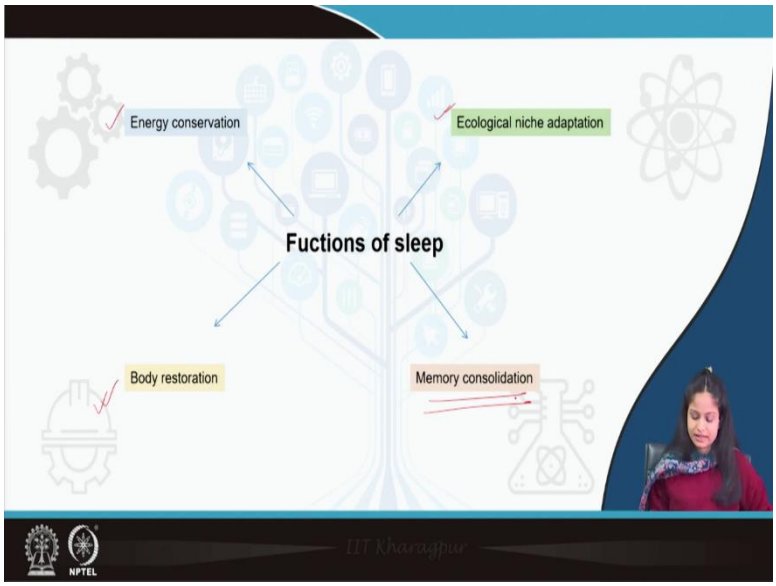
Now when the person is awake, what will happen, this wake promoting region will secret histamine. I told you the histamine is one of the neurotransmitter which keeps the person awake. So, histamine will be secreted to the cortex, the person will be active and histamine will

be secreted from the tuberomammillary region or the wake promoting region and inhibit the sleep promoter region. The person will not get sleep.

This acts with the help of suprachiasmatic nucleus as well as the lateral hypothalamus, which secretes or orexins or hypocretins. The other cycle, suppose in case of night what happened, the person will get sleep at that time the histamine will not be getting secreted. But because of the sleep promoter region, which remains active, this will release GABA. And this GABA neuron will inhibit the wake promoting region, this GABA neuron.

And there will be no secretion of histamine from the wake promoting region, so the cortex is also not active and only the sleep promoting region is active and there will be sleep. So, this is the sleep/wake cycle, which is on and off mechanism, which occurs along with orexin and hypocretin neurons in the lateral hypothalamus, as well as the suprachiasmatic nucleus of the hypothalamus, which is the body's internal clock, which is activated by melatonin, light, and various activity to promote either sleep or wake.

(Refer Slide Time: 32:39)



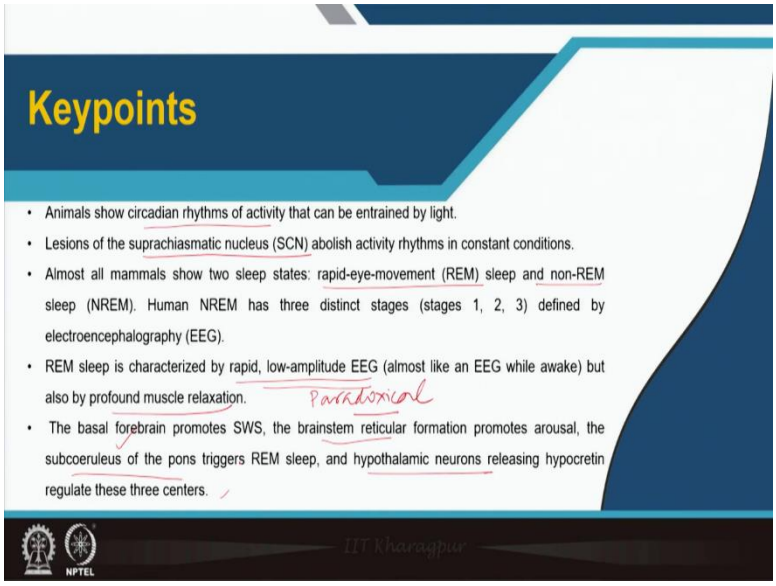
So, what are the functions of sleep? Why we need to have sleep? The first function is energy conservation. You have seen various metabolic activity. The heart rate decreases, the respiratory rate decreases, the muscle activity decreases. So, the metabolic activity decreases in our body. So, when you sleep, there will be conservation of the energy for further work, for the next day work.

Then ecological niche adaptation. Ecological niche adaptation means there are animals when they, at the time of day, there are certain nocturnal animals. There are certain diurnal animals. The animals which stay awake at the night, the animals which stay awake in the morning. Now why this ecological balance is required? Because if the animal who is nocturnal at night, that means that animal is awake at night.

But when that animal if becomes awake in the day, it will come out in the day. And if that animal comes out in the day, the other animals or the higher animals can eat that animal up so that, there can predatory other animals which will cause harm to that nocturnal animal. So, that is why there is a balance which is maintained. That nocturnal animals will be there, which will remain awake at night, and there will be animals which are diurnal in nature, which will remain awake during the day.

There is body restoration, there are protein breakdown which occurs during the various activities, so you need to restore your body proteins also that occurs during the sleep. And very important, memory consolidation. We always tell the students that before going to exams, you should have a good amount of sleep, though you do not listen to that, because the memory consolidation occurs maximum during your sleep. So, these are the major functions of sleep.

(Refer Slide Time: 34:40)

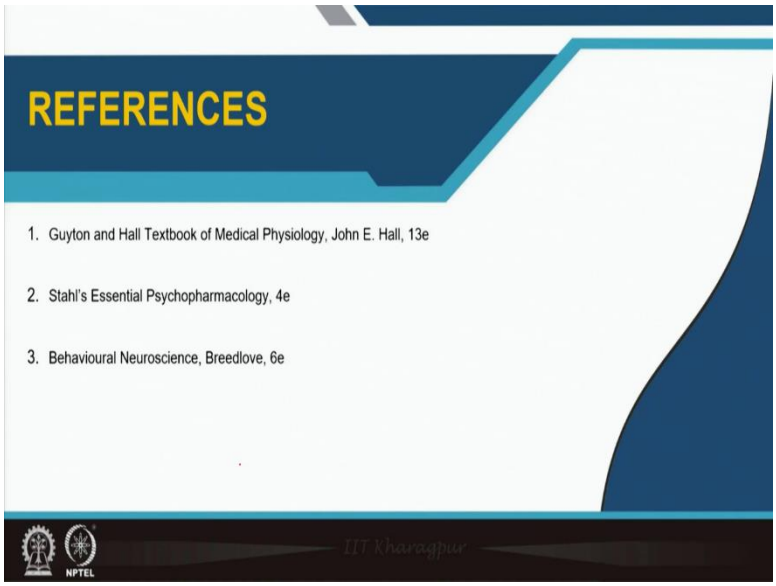


The key points you have to remember, the animals show circadian rhythms of activity that is usually entrained by light. The lesions of suprachiasmatic nucleus, they will abolish this rhythmic activity. There are two types of sleep mainly, the rapid eye movement sleep and non-

rapid eye movement sleep, which is further divided into three stages, N1, N2, and N3. The rapid eye movement sleep is mainly characterized by beta wavelike activity and it is also seen to have muscle relaxation, profound muscle relaxation. And it is also known as paradoxical sleep.

And the main four centers that is basal forebrain, the brainstem reticular formation, the subcoeruleus nucleus of the Pons and the hypothalamic neurons releasing hypocretin, they regulate the sleep and the wake cycle in our body.

(Refer Slide Time: 35:40)



So, this much you have to remember in sleep. Thank you.