Animal Physiology
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Lecture - 39
Hearing System

Welcome back to the lecture series in animal physiology. So, we are in to the week eighth. So, we have finished three lectures and if you recollect in the last lecture we talked about the neuromuscular junction, the last segment of the stretch reflex arch or I mean as independent also there are so many neuromuscular junctions all over our body, where the neurons are controlling the movement of the muscle and there we kind of marry that part of the muscle where I taught you about how the sliding filament happens between the actin and myosin filament which is negotiated or executed by the calcium ions. And in the last lecture I told you from where these calcium ions are coming because of the sensitiveness of the calcium ions via the ryanodine and dihydropyridine receptors.

So, today what we will be doing is that we will start talking about the special sensors. So, in the nervous system this is the kind of the last tail piece of 3 4 more classes where we will be dealing with special sensors are sympathetic and parasympathetic system, post that we will move on to the cardiac system and then followed by the digestive system like so on and so forth.

So, talking about the special senses. So, just before I proceed further this is our week 8 lecture 4.

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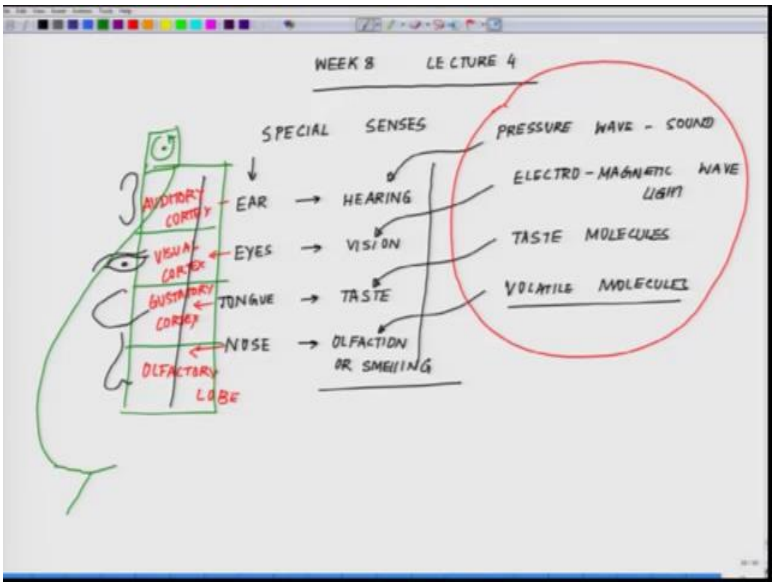

So, we are starting with the special sensors; among this special senses what will be dealing with are ear for hearing, then eyes for vision we have talked about the sensor radio sectors like stretch reflex and all which are handling your kind of a pressure or the stretch on the skin or in the muscle.

Then we will talk about gustatory receptor that is very briefly about taste and very little bit which human being does not use though all fraction through the nose fraction or smelling. This is more of canyons which I specialized on it. So, these are more or less the four special senses will be dealing with.

So, talking about the modalities in terms of the hearing, this is pressure wave or mechanical wave which is coming, vision is an electromagnetic wave which is light, pressure wave is sound this is taste molecules. So, they have specific sites and these are volatile molecules. These volatiles come and bind to the odorant receptors which are present in the nose.

Before going into the detailed anatomy and the physiology of this, let us talk about some of the very basic fundamentals. So, the way it works is you have a sensor in terms of all of them which are the sensors you have the eyes, you have ear, you have tongue and you have the nose. So, these are the different sensors these sensor apparatus has very specific sensing elements which upon interaction with the particular view or particular molecule which have been listed out here, generates a ionic current which activates the sensory

neurons which is supposed to carry the signal. So, this sensory input goes all the way through this spinal cord all the way to the part of the brain where these informations are coded.

So, in the case of ear it is auditory cortex in the brain auditory cortex in brain in the case of vision it is visual cortex in the brain, in the case of taste it is gustatory cortex in the brain and for all fraction it is all factory lobes which are present in the brain. These areas they are having the motor neurons which are sitting there they process these different stimulus which are traveling from your eyes ear nose tongue skin wherever all these and not only that even from inside your body as we will talk about the gut physiology, we will talk about places where there are acid sensing channels if there is increase in the acidity or something. Those channel senses it you have the pain sensing receptors you have the barrow receptors as series of such receptors which are there.

But the architecture is similar there is not difference in the architectural fashion; it is only the modular element changes. So, as long as you keep this brain map intact you will never do a mistake. So, the sensory receptor sensory neurons carry the signal all the way to the brain that respective area right what I just enumerated for you, people the auditory cortex for hearing visual cortex for vision gustatory, cortex for the taste all factory lobe, there you are having this motor neurons which are sitting, they process the signal out here and then they decode it and let you know what is happening.

So, it is pretty much the same thing as we talked about the reflex of course, the only difference is that between the reflex where the processing is exclusively taking place at the spinal cord level, here the processing is taking place all over into the brain. So, now, let us talk about the anatomy of this hearing ear. So, if you look the ear, ear is something like this ok.

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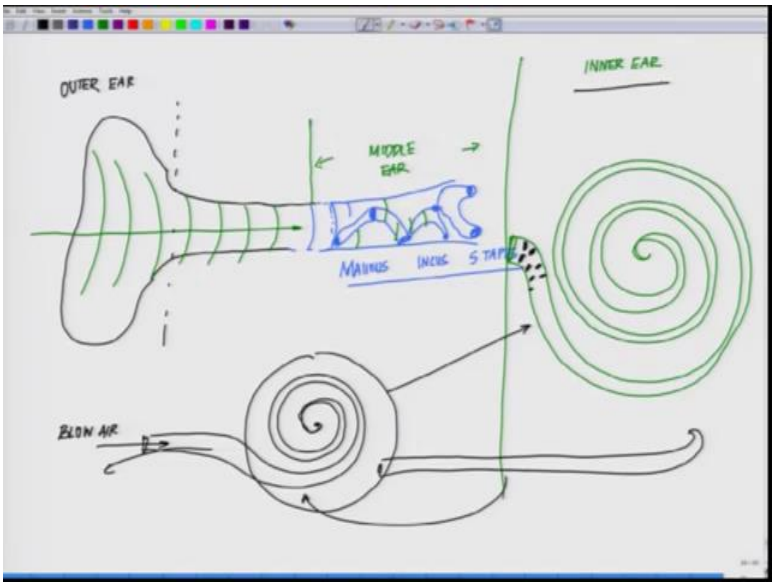

This is the external ear and I recommend you please go through any text book you will see this picture much better than I can draw here. So, this is outer ear, and the wave front travels like this along it ok.

Now, you have the middle ear. So, the membrane out here and you have the middle ear where you are having three different bones something like this, malleus incus stapes these are very soft bones malleus incus stapes. So, these special waves which are essentially vibrations these are now transmitted through these bones, which these bones constitute the middle ear. So, out ear it is the middle ear.

Now, from the middle ear the signal enters into cochlea, which is your inner ear and the structure of the cochlea is something like this. It is something like during your child you must have seen we have when you go to this fear or something you you blow it like this and something opens out and it comes back it is a curling thing something like this must have seen in all these fears like you know you seen this. So, you blow air once you blow air the siesta of kind of you know becomes straight like this and then as soon as you remove the air it again curls back to its original position.

So, exactly a very similar kind of this kind of structure which is present in the cochlea. So, our concern is the cochlea. Now if you look at the cochlea the structure is very interesting underneath the cochlea out here. So, this is kind of a very interesting

structure. So, you have these sensor elements. So, these black spots are showing you the sensor elements which are present there.

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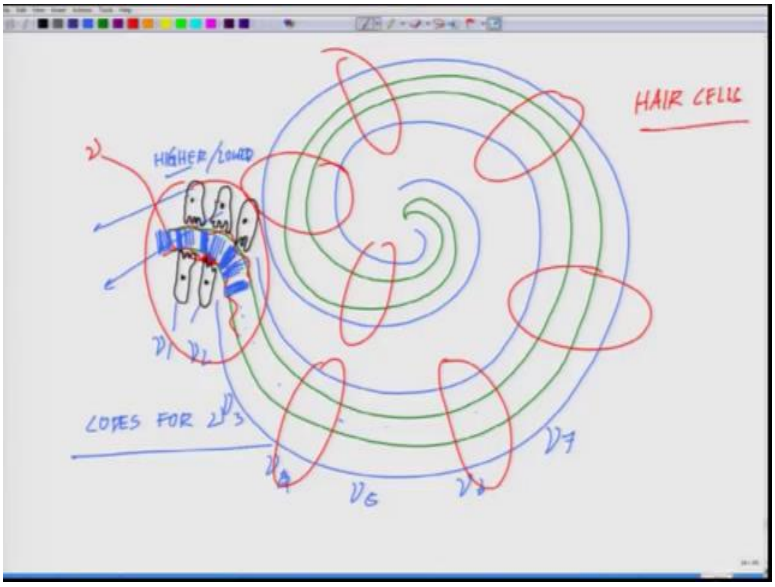

Let me blow up this picture here you have the; I will keep it I will not make it very complex. So, that you can understand, but this is way more complex than this. So, now, your sensor elements are sitting underneath like this. So, the sound wave which is coming the pressure wave contraction and rarefaction is travelling like this ok.

So, this is a semifluid field cavity and all your sensor elements are sitting here, and these sensor elements they were very peculiar shape. So, u detailed out the shape of it before I again I will come back to this picture. So, sensor elements look like this.

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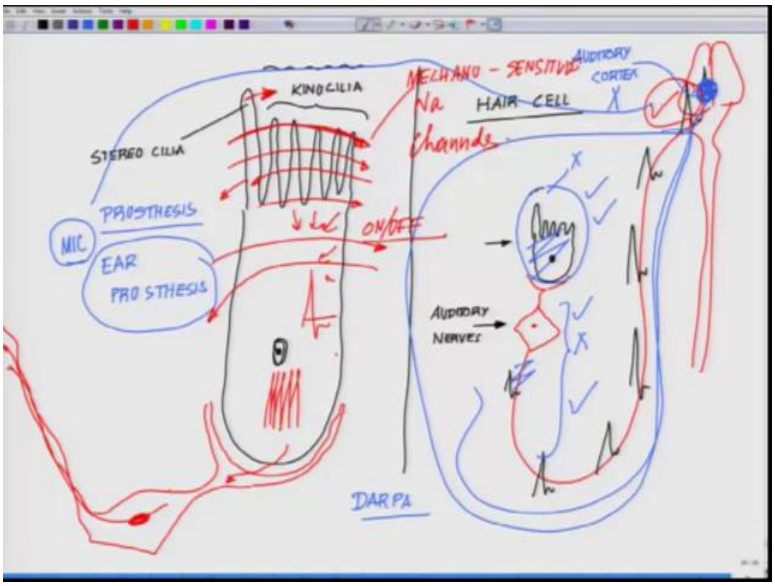

You see this hair like structures. So, these are called. So, this sensor structure is called hair cells, these hair cells have this long processes this is called stereo cilia and these other smaller processors are called Kino cilia ok.

Now, underneath it I will come into the detail do not worry underneath out here you have something like this or if I make it slightly smaller you will appreciate it better just drawing it in a smaller scale. So, here you have the hair cells which are sitting here shown by the arrow, here you have the auditory nerves, these auditory nerves carries the signal all the way to the brain and from the brain the decoded message. So, the decoding is taking place at auditory cortex and from there a signal is being decoded back right.

So, what I wanted to tell you is this in this circuit where all you could have problems. So, one of the places say for example, your hair cells and I have not talked about the function. Your hair cells are not functioning properly. So, the no message will go or your hair cells are all fine, but your auditory nerves are not functioning; so that case also signal will not propagate to the brain ok.

Now, think of a situation your this thing is fine hair cells are fine your auditory nerves are fine, but this auditory cortex is not functioning right, then to you only able to process the signal. But assuming that your auditory cortex is doing all perfectly fine out here then you can bypass this whole route this whole route you can bypass and you can directly connected to a mike artificial mike and if you have a way to integrate the auditory cortex

with this mike you will be able to listen not with that efficiency has the real hair cells you can and that falls under the prosthesis. The reason why I without explaining the second to this part explaining what hair cells because ear prosthesis was the first successor story or among the very first successor story of interfacing the brain with electronics, and understand these most of these experiments on most of this successful stories at their origins somewhere in darpan, which is depends advancement research program of US government.

So, some of these prosthesis were developed there functional one which really were implanted, and the reason to go for these kind of prosthesis also very straightforward because there are several soldiers in the field who get this kind of injuries because of sound of the shelling and all those kind of things. So, they incur injuries either in the auditory cortex or in the hair cells.

So, how to bypass it? So, they have these kind of prosthesis there. So, now, I having said this. So, you know the circuit the way it works. So, now, one take home message I will tell you first before I explain the hair cells how the hair cells works. So, these hair cells each one of this individual hair cells which are arrange like this all along the pathway, and same all along this pathway copes for frequency the take home exercise for you to figure out this happens in sequentially. So, now, figure out whether the higher frequencies are coded here in this part which is the beginning or the lower ones are coded here. Because if the lowers on coded here then eventually the inner will code the higher ones or if the higher ones are coded here then the lower ones will be coded inside.

Figure that out that I will request you figure that out now I will tell you how these are being how the mechanism works. So, now, each one of these hair cells which are present here they are coding for or a population of them are coding for a certain frequency. So, let us assume that from the lower to higher or higher to lower whichever way. So, there coding for nu 1, nu 2, nu 3 I am representing nu 4, nu 5 nu 6 nu 7 either it could be ascending order or it could be descending order fine. And now these cells are very interesting these cells when they get say for example, here when the wave front moves. So, you see the there are bulges happening on this like this because the wave front is moving and this bulge will be coded by a certain frequency and if the matching frequency comes.

So, this will lead to the bending of this hairs and this bending is a very unique space phenomena because if this one bends a one direction say for example, this bends like this all of them will bend rest all the other kino cilia if the stereo cilia bends like this, then all the kino cilia will bend an accordingly if the stereo cilia bends on this direction all the kino cilia will bend accordingly, and depending on the direction whether they are bending on this direction or they are bending on this direction whether it will be on or off. On or off means if they bend in one direction say for example, this will activate a series of mechno sensitive sodium channel and the mechano sensitive sodium channels are activated here there is a influx of sodium and kaitens out here, it will generate an action potential and that action potential from here will be transmitted to the next neuron and this will be carried to the brain.

And there will be a unique frequency coding which will happen because this particular hair cell is coding for a unique frequency. Now think of it if you have a sound coming at a certain frequency certain hair there are certain part of the system which will be responding to it and there are other parts which will not respond to it or if you have a mixture then it will distribute that which part is going to respond to which part. So, this is how your hearing happens. So, these are; so the take home message is very straightforward your sensor elements are hair cells, hair cells have kino cilia and stereo cilia stereo cilia decides in which direction they will move, depending on its directionality whether it will be on or it will be off is being decided right.

And this generates a train of impulse, that impulse is carried from the hair cells to the auditory neurons and from that auditory neurons it is taken to the brain and you know the message are being coded and accordingly we kind of realize what is the message all about. So, please do the homework what I have given you just try to figure out that how the frequency coding happens on that circuit higher frequency to lower frequency or lower frequency to the higher frequency please do that.

And apart from the function of the ear on this there is another function of ear.

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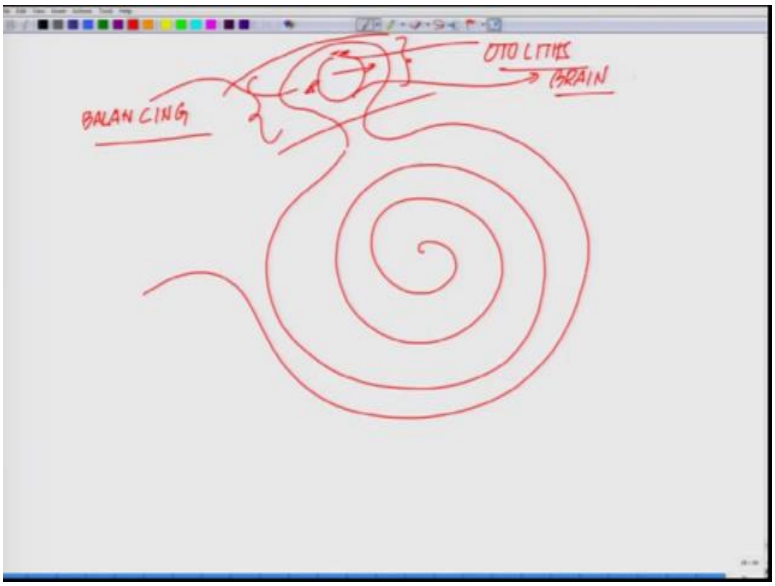

So, this cochlea what you see has one extension like this. This extension part what you see does not involve any hearing this part is involved in balancing. Something like you must have seen there are a person who experiences a vomiting feeling while going up the mountains or kind of continuously looking up like this you feel those feeling you about to vomit and all.

Such thing happens because here you have some kind of fluidic motions which are happening and these are transmitted to the brain. So, there is a balance area which is involved and the crystals which are involved in is called Oto Liths. There is a movement of this Oto Liths which regulate the mechano sensitive sodium channels to act and based on that the balancing act happens.

So, ear is not excuse. So, you must have seen there are people who put cotton plugs while climbing mountains. So, overall summery is that the basic circuit architecture remains the same, but it just how it is clubbed together. So, I will be closing here.

Thanks for your patience listening.