Bioelectricity

Prof. Mainak Das
Department of Biological Sciences and Bioengineering
Indian Institute of Technology, Kanpur

Lecture - 21

Welcome back to the lecture series in Bioelectricity. So, in the previous lecture, we talked about hearing; and the previous to that we talked about vision. So, among the special senses, in the beginning we decided we be talking about vision hearing, olfaction, taste and some of the skin related prop receptor and everything. So, we have covered the stretch reflex arc where we talked about you know pressure which is there through muscles spindle; then we talked about vision, where we talked about the rods and the cones; then we talked about the hair cells in responsible in hearing as well as in equilibrium.

So, this class we will be discussing about the olfaction or the smell from olfaction all the way to the gustation, which is basically taste. So, to start off with have you ever wondered why the mosquitoes kind of home around you in the night or some of the insect get attracted towards human being, what it is? Is it they have a fantastic vision, they understand that this is human being, so we should get amount of blood from them or rush towards them. So, if you look for all the vector borne diseases like you in the mosquitoes takes and the relevant diseases like malaria and sleeping sickness like using tse tse flies and all how they get attracted towards human being.

So, one possibility could be the warmth of the body the IR radiation, they have a sensor, they could sense, it is a warm body, and they move towards it. Of course, this is one of the mode by which they identify; there are other modes, some of the other modes includes they have a extraordinarily well developed olfactory system which is not that well developed in case of man, because we rely a lot on our vision instead of our smelling abilities. Whereas if you see a dog, a sniffer dog, it can smell lot of things, which to human being with it is very limited repertoire of a olfactory receptors unable to do. Whereas in the case of insects, they are even much better, they could distinctly smell the smell of your sweat or the body odor, they could distinctly smell the octinol nonanal, these kinds of compounds which are found in your sweat or they have very extraordinary carbon dioxide receptor.

So, if you look at these insects, they get attracted towards you by the plethora of receptors in their antennae by virtue of it, they could detect the smell and not only that they could detect the smell, it is very interesting the odor plumes. Say for example, there is a kind of an odor coming out amniotic from my body. So, it forms a plume all those volatiles which are there, which are forming a plume and these insects, say for example, the insect is here it could follow the plume either it will like or dislike it. Say for example, one of the chemicals called deet this is a mosquito repellant. So, whenever it the mosquito experiences a plume of deet, they repel and they run away from that or they fly away from that source of that smell or some kind of mosquito repellants or some kind of ointment what we put on the skin.

So, this all these things are being processed by a well-developed olfactory system. So, here, what we will do I will just give a overall outline of it, and we will discuss about just the same way we have discussed about vision and we have discussed about hearing. We will be discussing olfaction and then I will give you some very specific example from the insect world telling how these studies are being conducted, and what are their ramification, how these studies are helping the economic entomology where specially the tropical insects or tropical diseases specially the vector borne diseases where it comes. So handy and few other references which I wish you people should go through in order to enrich your data base of or opening up your window to see how these different electrical signals are being exploited in order to develop different kind of modalities to count a different vector borne pathogen.

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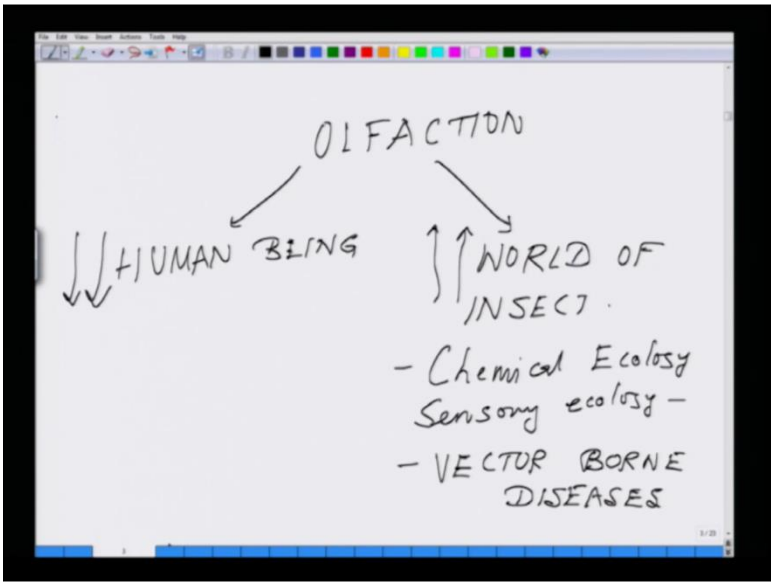

So, let us start the lecture number twenty-one. So, one second let me save it. So, here we will be dealing with olfaction and gustation. Gustation is taste, and olfaction is your smell. Within olfaction, we will be dealing with the world of insects, and this whole area falls under a domain of chemical ecology or it is also called sensory ecology. In case of human being, which as I have mentioned has a fairly low olfactory ability as compared to the insect world. Here we will be talking about some of the vector borne diseases.

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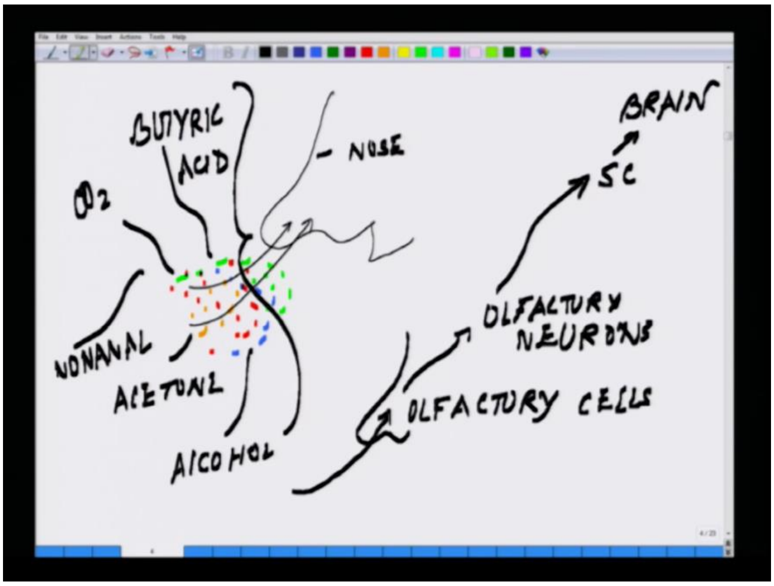

Now, coming to the basic architecture again we go by the basic architecture first if you look at the basic architecture, so say for example, this is for the olfaction your major is the nose. So, what essentially happens, you have these volatiles which there are, so these are the volatile molecules all over the place different kind of volatile molecules in red and as well as orange, blue, green. So, these are the volatile molecule, which are experienced by our nose, and we detect a certain smell. So, from the nose, there are specific cells olfactory neurons, first of all olfactory cells you can call them the one which receives the signal and then through olfactory neurons, they are all neurons though. These are the first line all the way goes to the through spinal cord, it goes to the brain and decodes the message, and this is what makes you feel that say it could be acetone, alcohol, CO 2, nonanal, butyric acid likewise. So many different smell a plethora of different smell.

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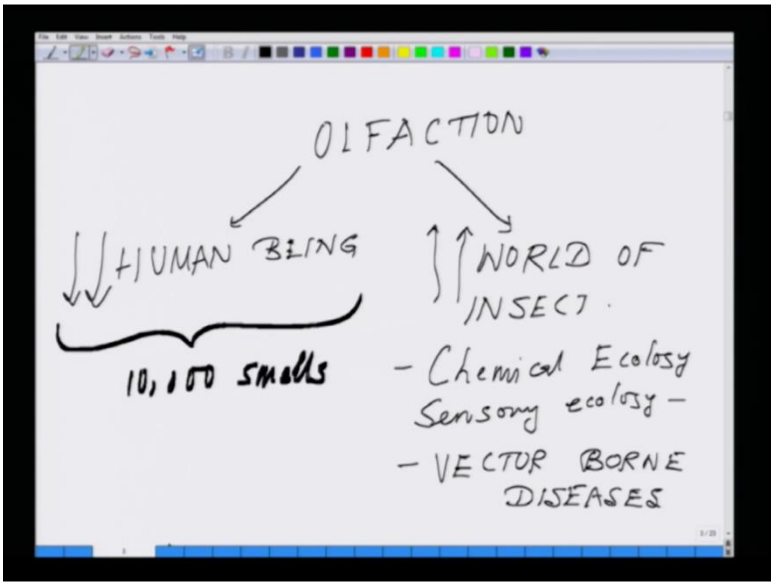

In the case of human being, if you see human being at the time of their birth could detect approximately ten thousand different smells. And it is being observed with age this ability to detect smell after fifty years with the onset of the ageing the ability to detect smell takes a downhill way. As you grow old, you detection limits kind of goes on decreasing.

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Now, coming back to the basic architecture how it looks like. So, the level of nose if we kind of you know magnify this further out here, something like this. It looks like, so these are the very specialized neurons, which could which are the kind of this olfactory receptor cells, these are called olfactory receptor cells. Then you have the olfactory glands, which is sitting out there in between which is more like a structure like this. This is the olfactory gland and this could be divide in two parts essentially this part is called olfactory epithelium, and out here this second level is called lamina propria and here is the olfactory bulb.

So from here, there are series of neurons which takes the message for further coding. And out here this is the zone where the different olfactory molecules or the volatiles kind of binds something like this, in the yellow and the pink color what I am putting the dots out here, so these are the different olfactory molecules. So, essentially what happens is this, these molecules goes and bind on this surfaces of this; once they bind, they open up the sodium channels and there is a flux of sodium and this flux sodium leads to change in the electrical signal. When this electrical signal eventually travels all the way and through the synaptic connection is transported here, and this is the way it goes.

So, it is very simple circuit, but each one of these cell types has the ability to distinguish or detect one specific kind of odor to the maximum ability that does not mean that it cannot detect another odor, but generally the way it looks like is that each type has the ability really combinatorial. They have the ability say for example, if I have three kinds of volatiles say A, B and C and D a four kinds. So, this will be A type, this will be B type, like this there will be C type or a D type. So, there could be ten thousand different types or twenty thousand different types and what essentially that means is that A has the maximum ability to bind to if this violet ones are the A molecules if I assume, the maximum bind will be of the violets maximum receptor will be of the violet as compared to say the pink one which maybe you know B type.

So, this is how these specialized neurons have evolved and this architecture, so this is out here what you see actually essentially is the nose, so this is if I had to draw a nose it will be almost like this. So, this is underneath nose that is where the volatiles enters, and this is the circuit to follow. And these are the ones which are sent to brain and in the brain there are specific cortical areas where the processing starts and then based on that we decode the message.

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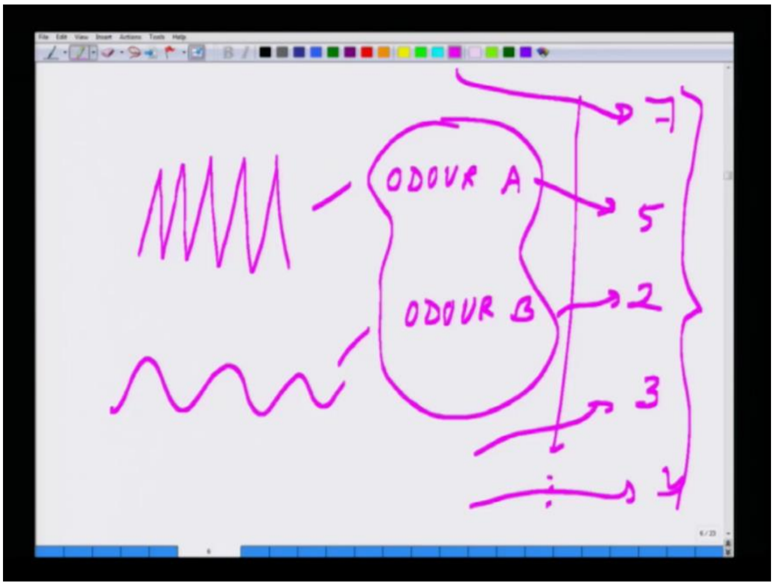

So, essentially what it translate out to be is this for every odor say for example, a pungent odor or something, there is a unique electrical stimulus. A electrical stimulus codes for say odor A, for odor B likewise; and each one of them likewise goes on. They have a combinatorial mixing of say odor, give a quantity five units of this signal, two units of this signal, three units of another signal, four unit of another signal, seven unit of another signal, and then there is a combination of this permutation and combination by which we get a unique odor for every individual component we smell. So, understand so basically those ten thousand neurons are doing a lot of computation, little bit of signal type A, little bit of signal B, little bit signal C and that results in a totally combined or totally different kind of odor. So, whenever we smell something, it is a smell something like this, something like that, we are unable to really detect very clearly. So, this whole combinatorial geometry is very interesting, and how this is being dissected out this is very interesting.

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So, from here I will take you to the world of insect where these all these things are being detected. So, some of the modern analytical chemistry tools come fairly handy in deciphering some of these receptors. The way it works say for example, so this is a simple electrophysiological setup coupled with a gas chromatography setup. So, if you look at a insect, a most of the insects kind of you know looks like this, or if you get a side view of a insect it is something like… So, their major olfactory sense organ olfactory organs are here their antennae.

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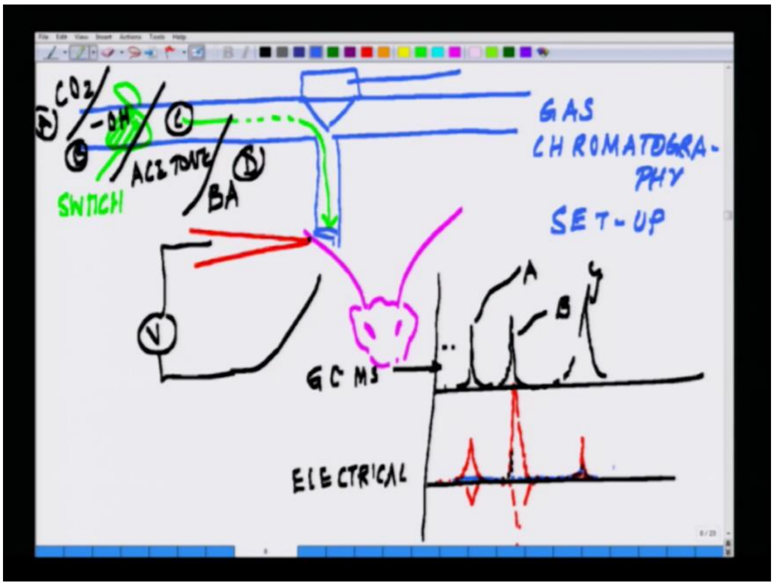

So, now what you can do is say for example, so if you get to fix an insect like this with its antennae's like this. Say for example, so mouth I am just showing the face of the mouth like this and very close to the mouth you put an electrode like this we should be able to you know record from the mouth. Now, on top of that you have a smell injection setup, it is a juicy column with it is analyzer sitting out here. So, this is a gas chromatography setup, and through this volatiles which are flowing by are released. So, you have a controlled release, so you can switch on and off out here. So, you have a switch and here is the electrode you have, and this electrode is connected to certain voltage of the ground electrode very close by…

Now, you get in your reading panel, you are seeing say for example, from here I am releasing three gases. So, CO 2 alcohol or OH, I am just putting OH and acetone, and say butyric acid – BA, these are the four volatiles which I am going to release, and the sequence of it will be A, B, C, D. Now my hypothesis is this that this particular mouth the antennae of the mouth could smell ethanol or OH. So, now I allow this CO 2 eject out and here is the electrode sitting touching on the surface. So, if this is so, this is say for example, the g c p saying that. So, this is scale is showing the upper scale is showing GCMS, you could attach it with the mass aspect. If you have a unknown thing, so this is the g c scale and here is the electrical signal. If it has a CO 2 sensor which suppose this is A then there will be an electrical signal, you should be able to see in the lower column. If it does not have then you would not see anything, it will just go like this.

Now, if we hypothesize that it has a sensor for B, it has neurons, which could sense alcohol. So, in the alcohol will be alighted out out here, if this is for b. Then I should be able to see a sharp heavy signal of electrical signal out here; it could be both sides. It could be like this also you can draw it. I am just drew it in the upper side just as a convention and nothing else. Now, say for example, now you are alighting out C, this is the signal for C. So, you should be able to see another electrical signal if at all it has receptor for C or you may not see anything and it will just go like this.

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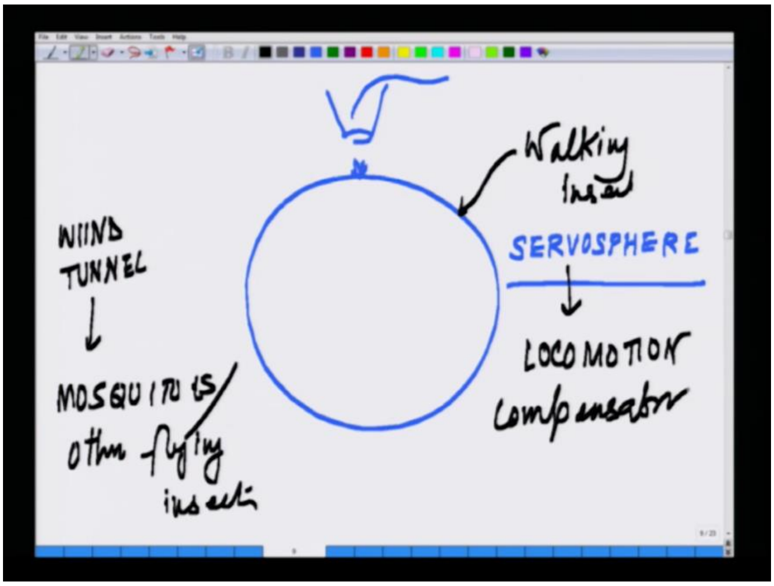

So, this kind of setup of GCMS coupled with electrophysiology is what is used for these kind of insects, and of course, you can further verify it using certain behavior where you have these kind of spheres if it is a walking insect, and you have the odor plume coming from here. And you allow the insect to move on it. So, this is a model of a servosphere. So, if you ensure that there is definitely for alcohol, it has an affinity what you can do you can put the insect moving insect if it is a walking insect of course, otherwise if it is flying insect then you have to have a wind tunnel. On a wind tunnel from one side you have to give the odor plume and you have to see whether the insect fly towards it or not or it repels towards it. These wind tunnel assays are being done for the mosquitoes wind tunnel assay for mosquitoes and other flying insects; whereas for the walking insect you use something called servo sphere or this is also called locomotion compensator.

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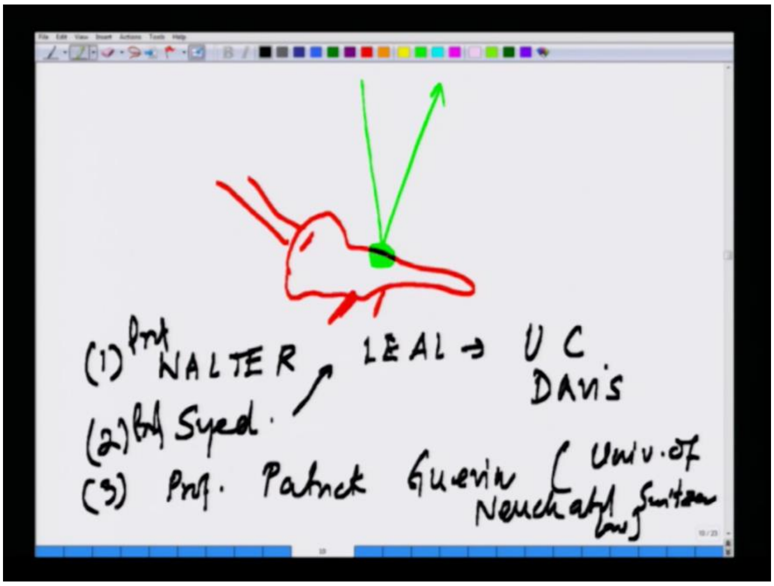

Locomotion compensators are very interesting thing say for example, what happens in locomotion compensator. Say for example, this is the walking insect. Now on top of this, you stick some certain specific material, which could reflect the light like this. So, a locomotion compensator is something like this, say for example, so in top of this if this insect walks in suppose the odor plume is coming like this, and this insect walks towards it or on this side. So, based on that on top of this is you have to imagine a three dimensional because this is from the surface it is coming the odor plume and the top there is a sensor. There is a sensor which will tell you if the insect moves in this direction, it will this is fairly compensate and will come back to it is original position.

If it is moves in this direction, it will compensate, and will come back to its original position. So, essentially it will allow the insect to be in the same position facing the plume of the volatile. And if the insect does not really like it, it will turn back and it will start moving towards you, while you are looking at this is fair. So, I will request you guys to really look into the servosphere and locomotion compensator, because this is not within the purview of this course, I mean this is behavioral assay if you find really wonderful results in the GCMS column, you can really see the servosphere, but it is something very interesting.

And for this kind of work, you should refer to these work of some of these people like you know, you should look through the work of Walter Leal; Walter Leal is currently in

U C- University of California at Davis. You should see the work of one individual who is currently a faculty, you should see the work of Syed. He has worked with Walter Leal currently he is I think university of Nebraska, where you should see follow his work. He has worked in mosquitoes, you should see the work of Prof. both all them are professors, Prof. Patrick Guerin in university of Neuchatal, Switzerland. These are the people who there are many other names which I will just try to pull out some of these references. You should look for their work because they have done significant amount of work in last twenty to thirty years in this area, where some of these servosphere have been developed.

I will give the original reference which was done by Kramer who actually developed it in 1976 the servosphere model where you can really see, you can do the computation. But in the area what I essentially wanted to highlight, the reason to you know expose you to these kind of areas is this that the world of electricity, bioelectricity is very wide very very wide from the insect world to the human to the plant, it is all well spread out. It is essential that you have to keep your mind open to you know appreciate all these things, because I mean just forty lectures or forty fifty lectures is not sufficient really it you know kind of open yourself up to the whole world.

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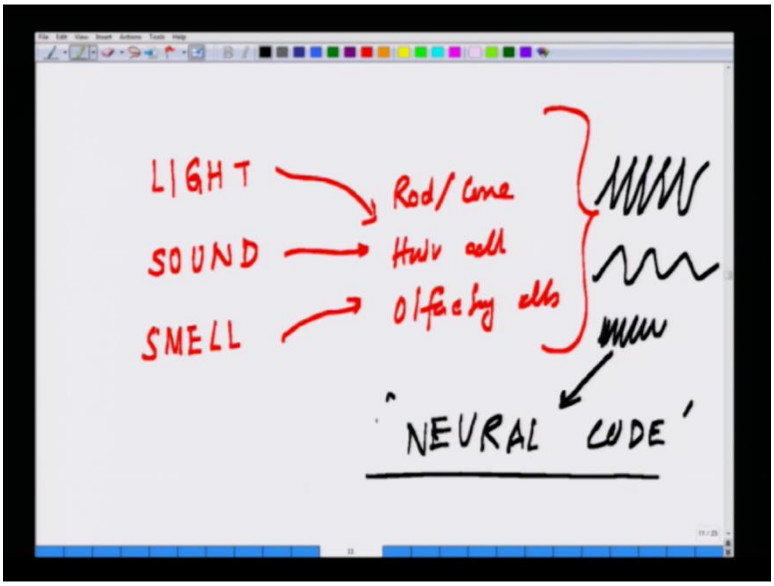

End of the day you have to realize, it is a simple computation; whether the modality may change, modality may be light, modality maybe sound, modality maybe smell or olfaction. But end of the day they code an electrical signal through of course, rod and cone or for a sound, the hair cell for smell, olfactory cells likewise. But end of the day they all codes certain unique electrical signature, and these electrical signatures essentially falls under the whole area of neural code. And this is where we say we call an apple an apple, because there is an unique neural code for an apple there is an unique neural code for a grass, there is an unique color coding, so that is what makes our whole world around us.

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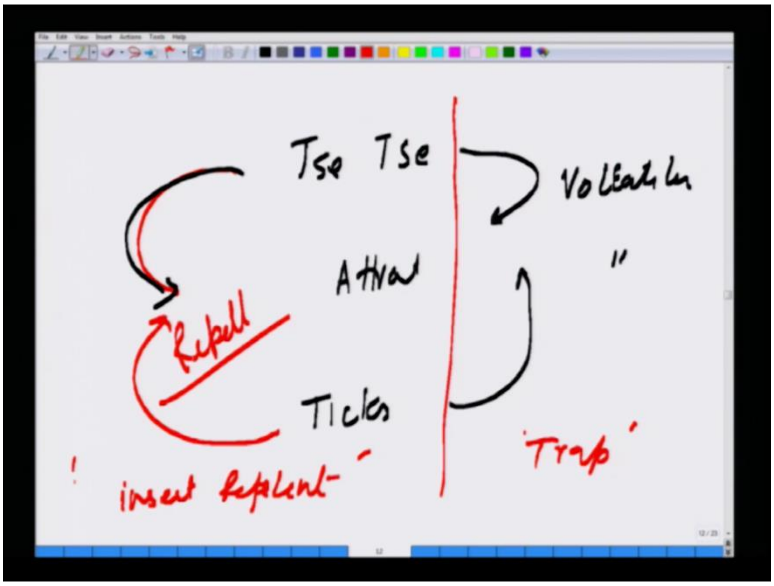

So, very interesting, in the same line touching upon this since I have touched upon the olfaction, I have given you a very brief exceptionally brief outline about how these are being used. How you could visualize these kinds of models where it all goes. Say for example, Tse Tse mosquitoes, if you know exactly what kind of molecules or volatiles, they are getting attracted or say for example you talk about ticks in the temperate countries this is a huge problem.

If you know the volatiles, which are attracting them or repelling them, both ways you know attract or volatiles, which you know let me put a different color code for it or the volatiles which you know repels them. So, you can develop if you know its attracting then you can develop a trap, where you can trap them because they will be coming close to it, and if you know it is a repellant then you could develop an insect repellant. This is a whole area of amazing research, where entomologist along with the electro physiologist are utilizing or exploiting the electrical properties exhibited by these different insects to device methodologies against vector borne pathogens.

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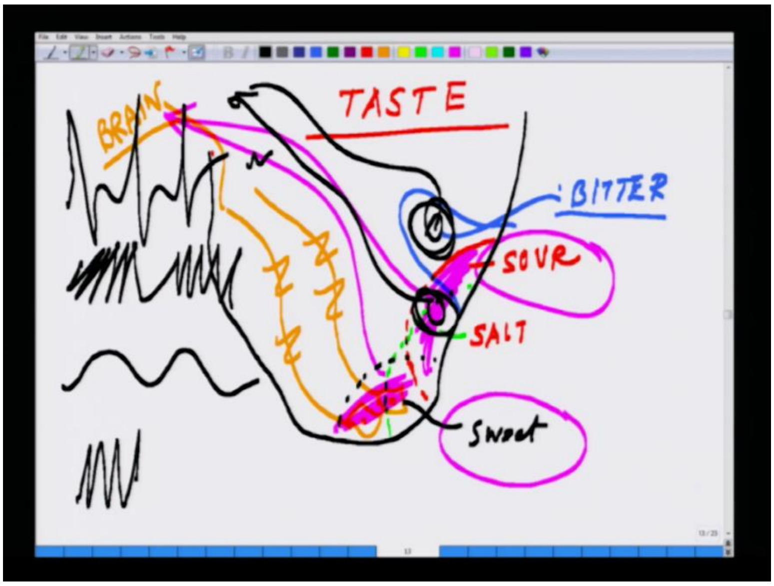

So, from here, I will just take you to the world of taste or gustation which is again in the case of human being, starts declining after the age of fifty. But I will just give you a very briefly kind of if you look at your tongue then this again gustation is a very interesting topic, in the case of insects. Because if you look at it, I mean you see a lot of insects along in a cow dung or you know all these kind of places or along the dustbin and everything, trash why is it? So it means they could taste certain material, which we cannot of course, you know for x, y, z reasons.

So, gustation is again very highly evolved in several lower animals; in the case of human, if you look at the tongue, the structure of the tongue which is involved in it, it is something like this. So, if this is the structure of the tongue then you will observe that there are different areas which have different role like the tip of the tongue. If this is the tongue is involved in sweet smell, whereas there is a area which is now I am putting in like kind of you know hatched area which is kind of involved in sour. Then similarly, there is another area which is kind of overlapping which ensures your, just I made a mistake actually this is the sweet and this is essentially is the salt and this is the sour area and then you have certain areas like you know which ensures for bitterness.

So, if you really look at all these things. So, from here what essentially this tells you, this list can go on and on there you know into this. So, what is essentially says underneath these structures, there are specific cell types. These cells carry the message based on that there are sodium channels which are opening, and they are generating a specific kind of electrical signal. These are carried all the way to the brain and that is where we decode the message. So, for individual type for the sweetness, for the sour, for the salt, for the bitterness, there are specific kinds of cell types, gustatory cell types which are present. They ensure that we kind of there is always a combination suppose we have something which is slightly sweet and sour.

When we talk about less sweet and sour chicken or sweet and sour vegetable what does that mean what technically; that means, that you are tasting something which has a sweet component as well as sour component. So, the electrical impulses are generating from here electrical impulses are generating from here and the brain is pretty much processing these two together and telling you, it has a sweet and sour taste or something as a sweet and bitter or sour and bitter or salt and bitter. So, basically there is a computation which is taking place out here as well as out here, it is something which has multiple taste.

So, end of the day what is the most important key point is they are activating the sodium channels, and those sodium channels are leading to electrical signals. So, for sweetness, anything which is sweet there is an unique electrical signature; and obviously, for the saltiness, there is another set of electrical signature or some this is just I am randomly drawing. So, do not think that you know something for bitterness, there may be something like this. So, they are all unique electrical signature which are being transmitted at a different phase with a different frequency with a different kind of density and these signals are being deciphered by the brain, and based on that we understand what we are smell, what we are tasting.

So, if you look at this whole, if I had to summarize this whole special sensors what we have talked about the vision, hearing, olfaction, taste, you will see all of them have one common feature, they all code. If I have to summary of the special senses are vision, hearing, taste, smell. They are all coding, they have one common feature, they all code for, they are all translated into electrical signal. They are all involved in sodium channel, potassium channel, chloride channel likewise. In these all are sent to the brain for further decoding. This is the overall if I have to give one small Lehman summary, this is how it looks like.

In the case of vision you have rod slash cones taking care of colors. You have the hair cells, you have taste neurons, you have olfactory neurons and then you have touch neurons like and so on and so forth where all of them follow these. They all have a electrical component; all these ironic component, ironic electricity which is eventually sent to the brain, and this whole area of coding is the final frontier where mankind is heading is neural code.

What is a neural code? In other word, a question could be asked could we hear a image? In another word, you are seeing something and this is connected instead of in the brain to the visual cortex we see or say for olfactory cortex - OC and for hearing auditory cortex – AC, say for example, a visual connection goes all the way to auditory cortex, what will happen? Or a hearing goes to visual cortex what will happen, a taste or a gustatory receptor goes to say a auditory cortex what will happen? These are the questions of the future where we are heading where many of our answers lies about who we are in solving those wonderful questions. So, I am closing on here. In the next class, we will be talking about the learning and memory and all the higher functions of the brain.

Thank you.