How The Brain Creates Mind
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Lecture - 11
Cognition and Emotions-1

Welcome to week 3. I hope we are progressing in some sensible way, last week towards the end we talked about the oscillations of the brain. So, it is like we have gone to the basics micro and then we have forming and they were seeing how it was oscillation, we talked about and how the brain oscillations actually are use to carry information, modulate information, differentiate integrate. And how basic oscillation is going on over and which depending on the activity which brain is doing and depending on the area, the frequency modulates. And then the brain synchronizes at really goes in to lower frequency.

But how this whole idea of network, whole idea of how do this still it does not explain. In spite of knowing this oscillation, this is what we are seeing from outside where recordings and by modeling, but how are this networks connected. This was the big question towards the made of last century. And the first answer which came from; was not from Neuroscientist; it came from computer sciences actually.

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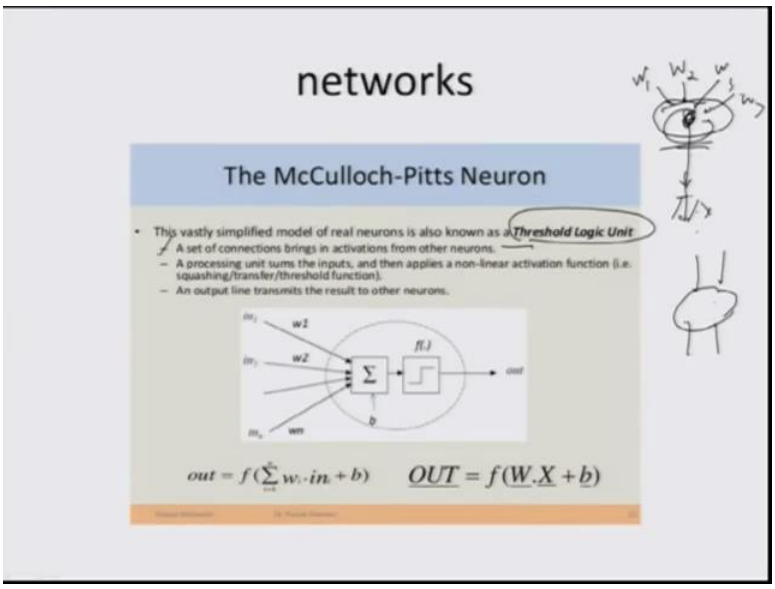

And this was the first module which actually came what we call a McCulloch-Pitts Neuron. A very simple thing he use the logic of computer and the logic of what we you know as Boolean algebra, 0 1 binary set of information which keeps the signal going. Like each signal can be represented in the form of binary signal.

So, what he brought out, the McCulloch-Pitts model that and the idea was brilliant because neurons, if you go back at the action potential they do not fire till a threshold is crossed. So, from 70 milli volts analyze they come to 50 minus 55 milli volts they will not fire. So, for that to become a single neuron; can a single input can never bring it to it. So, they have to multiple inputs and that is where 1000 to 10000 neurons converge on 1 in each one of them further. And this excitatory portion optic potential and innovative portion optic potential they unite to bring it out threshold, this idea was I am the brilliantly chorded actually, this and it is a real neural model is thresholds is a threshold logic unit; that means, unless the whole input goes to a threshold, there will be no further output.

So, the idea was the set of connections, brings in activation from other neurons, Right, this is a neuron 1,2,3,4 and then, A processing unit processes it and then puts a output which is goes to other Neurons. So, what this said that, this is the whole thing this process of input and procession. The processing the information is like that, each of them have a weight, and the summation of these weights, besides what is going to be the output and this a non-linear thing, it is not a one comes and one will go out 2 come and 2 will go out it is not like that. So, this whole summation process is a non-linear process which the call is (Refer Time: 04:16) transfer or threshold from which is for the first model and it became very popular, but there was issue with it and the issue was that the brain does not function in the binary way.

It may at as level of single neuron, but the question is that the output is very complex output is so all though this process of the whole thing of summation could have been non-linear, but the output by these neurons have to be a linear thing, but then does not worth like this, the layer of complexity the behavior, the type of processing does not fit in; plus also, but this was the beginning of whole not the beginning I should say, but it is a big in Pitts to what the whole computer artificial intelligence (Refer Time: 05:04) you can train the neurons, by putting in different weight ages, but these brain also remembers brain is plastic, it modifies these neurons did not have that capable thing this module

because you sudden inputs come there apply go, how I how is it going to modify this \not explain.

So, another idea which came was Perceptron. Perceptron was a very weak the popular thing, but and that was big fillip to the artificial intelligence, but had it is own criticism because; obviously, brain I am sure does not follow one simple physics which so, but following this was happening around 2nd world war.

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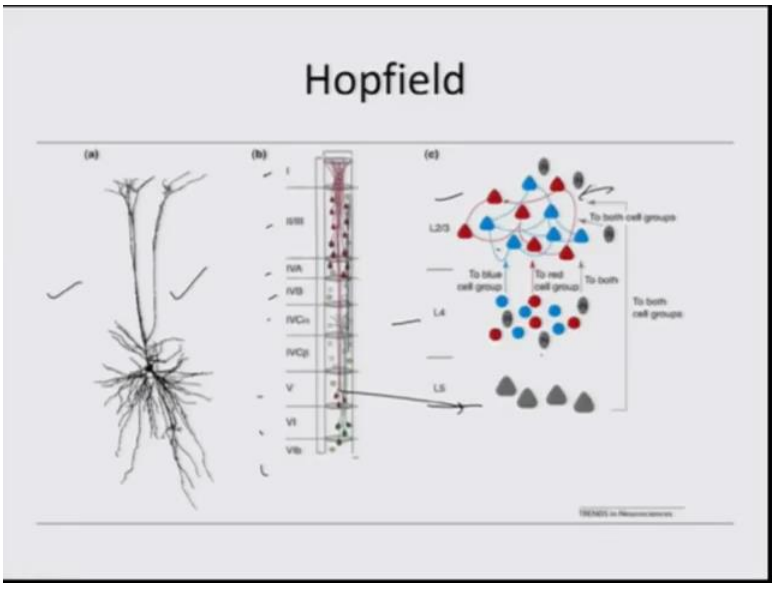

What came out was a Hopfield brought out, the Hopfield module is interesting and Hopfield actually brought the whole idea not form neurons, but he was thinking about magnetism and the best I mean what actually was his big question was, that in a magnetic field how this is a memory, this is a memory of the how does it happen possibly in a magnetic element which have if they are saturated; obviously, they has a they cannot be a current flow, in the cannot be magnetism.

So, these magnetic elements of free floating electrons and there has been. So, within a magnetic material, there may be pockets, where all the things are aligned in same way and continue to remain the same way because that is the memory. So, of magnetism we know has a memory. So, he brought out the idea that the same thing may be happening with neurons, that it is the same set of neurons; may be differently indifferent pockets which align together in their activity he took out of model from already publish paper by Hebb we will talk about (Refer Time: 07:11) been thing and he brought out the idea of

associative learning, now if you see this just a simple thing, these are neurons, these are layers if you remember one. So, 2, 3, 4 be 5, 6 this is a pyramidal cells,

So, layer 5 is this which is pyramids pyramidal cells which fire layer 4 way this is the lot of input and layer 2,3 from pyramids this is the type of cells which exists and this is the type of network is deformed. So, blue will go to blue, red will go to red, and this is going to all the cell groups.

So, their single cell layer, then there are multiple type of cells, is multiple type of cells from another network among themselves, as they grow higher and the single cells give connection to everything.

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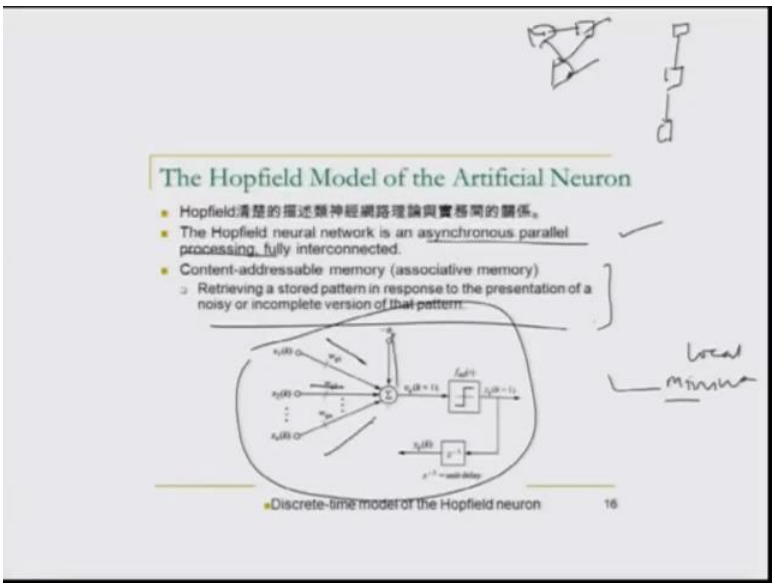

This is the type of associative network, and is a synchronous parallel processing, they can be a random parallel processing, synchronous parallel processing, they can be random fully interconnected now this is a good example which is given in one of the books called demystifying brain, by I think which is Chakravarthi which is available on the NPTEL site, this was the best thing. Basic thing is it is content addressable memory. What is the content it is memory suppose I have to tell you. For example, take rose, now if there is an if it has been a very very linear type of stuff, then first if I tell you about rose the first will have to remember R O S E, then you will have to look at the shape may be then the colors of the petals then the feeling of torn pricking or (Refer Time: 09:21) the time, time is a problem, where in does not do it like this.

So, Hopfield brought out this idea, that even if an noisy or incomplete origin of the pattern is stone in the brain is given, is still the whole memory can be activated you try this, if I ask you to just think of rose; you see how many things come in to a mind, even if I give your plastic rose, even then the memory of rose can come, If you tell the child or a for apple a for apple so it just a. So, everybody knows A for Apple for R for Rose. So, it means, instead of storing memory part by part, what you do is you have associative memory.

So, any stimulus here or here or here can retrieve the whole pattern, this was Hopfield's model, it was by what he said that, all this once some stimulus goes in, an brain tries to remember all that, and brain tries to form associations in the process of learning they may be high energy maxima, but ultimately when the memory settle, there is something called are minima a local minima, where the energy level of this whole thing settles down.

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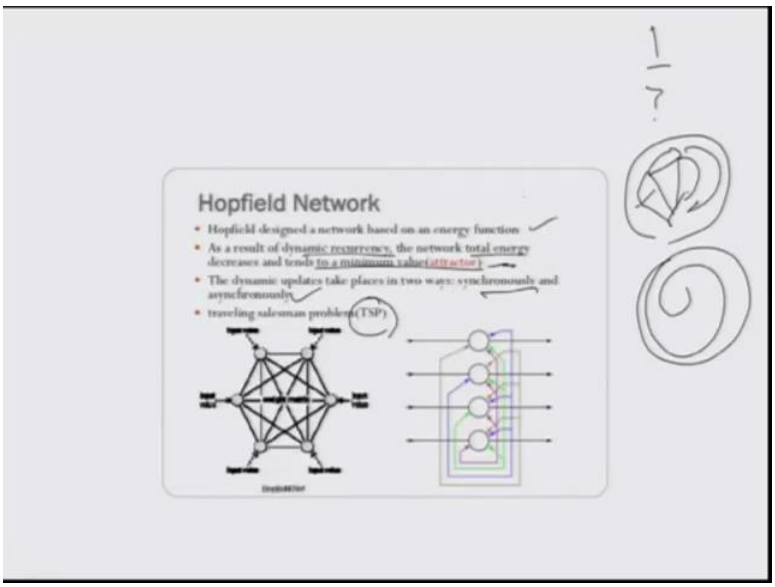

So, he was actually using McCulloch Pitts formula of weighted is stimulus coming in, Right; then this gets into process the association is the most important thing, this design and network based on energy function. So, he introduce the topic the concept of Re currency, he said if this is associate, networks are associated with each other and connected to each other, it is not just once that the thing goes and settle down; it is the lot of feedback loops, it keeps firing recurrently; till it reaches as a result of re currency, the

network total energy decreases and tends to minimum, which is attracter sage it is the term from non-linear dynamics you know attracter stage, we are symptoms can naturally tend to go and settle down.

So, he said these low minima, local minima of energy are the attracter and that is our memory is formed. This can happen us synchronous way or a synchronous way, there is a very famous traveling salesman problem, we can always read that; if are salesman has to find there is go to do find somebody, because that is the process, but brain does not work this way.

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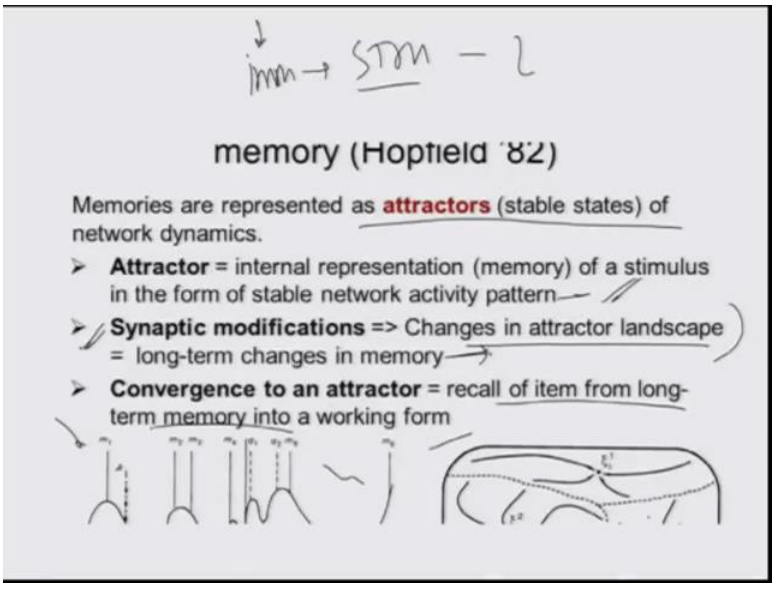

So, essentially a traveling sense, salesmen can find out a network which. So, memories are represented as attractors there is stable state of network dynamics and what is attractor it is internal representation of stimulus in the form of network. So, anything which goes on into a mind has to be there, to be represented to be and wide if you remember now I told you that anything comes to you1st the basic systems of the brain will evaluate in the it on the hierarchy of survival thread and that is we are why in requires.

So, many neurons and that is why we are requiring the network and synaptic is strength of. So, many neurons because was simple reason, that all this information and things which are going on in to your head your mind should know it, because what will

maximum things, what will bring in the thread, what will bring in the survival problem we really do not know at this point.

So, that is the basic attractive where representation of that memory is stabilize at all basic energy level the changes in attractors are the synaptic modification. So, how does you do that attractors say essentially means that between those neurons, they must be existing on a certain stage of synaptic connections, we stimulate them; to the fresh thing repeatedly. They keep firing, the synaptic shape changes, it may be a temporal change or a special change; because if it changes, that change is preserved. So, next time, when the stimulus is gone in. So, that that is the now you understand there is something call a immediate memory, short term memory, long term memory, if immediate is something is presented to your brain recognizes it; if it is already seen, if is not seen it will try to remember it in the short term memory. This recurrent firing will keep happening in associative form lot of neurons in network will get associated to take all the feature attraction of that is stimulus.

So, that everything of that thing possibly goes in, whatever gaps are brain will put it back from the gestalt memory you know, if remember it talked about. Gestalt this changes, the whole synaptic geometric, was the synaptic geometry is changes after few minutes, whatever by rehearsal, by training, by repeated is stimuli of the every time; a dog comes and bites you, that will going to long term memory. All the doc bites you, so severe in the first time, it will alter the already existing synopsis, that may become permanent goes to long changer. So, what happens, every time this is stimulus is presented, you are the recall will happen from this long term memory, because you already store there. So, the brain that network has to just recognize one part of even if it is a noisy stimulus, even if it is incomplete the brain will recognize it and it will start moving.

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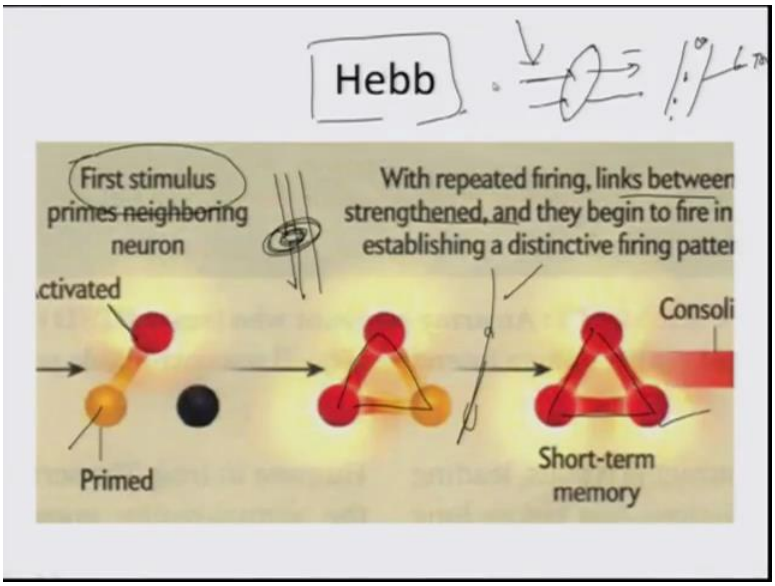

This was actually based on Donald Hebb's work. Donald Hebb's simply runs saying it simply with rest of for inter think, Is a neurons that fire together, were together; that means, the first stimulus first time a stimulus goes, this is activated and them neuron is an neigbourhood is also activated, Every time you keep firing, this network will get a strengthened. So, every time the pre synaptic neuron and the post synaptic neurons are fired together, there is synaptic distance will keep increasing and they will always fire together, that is the basis of short term memory. So, there is a Hebbian way of learning which is the most common the links between neurons as strengthened and they have a distinctive firing pattern. So, every time this comes they will together.

So, once they, this is a short term memory, this fires, this fires again this fires, this fires this is very strong. Every time this will fire, this will fire. So, memory will considered and then synaptic changes happen, as I told you in how (Refer Time: 17:50) that leads to long term memory, this happens in the area called “Hippocampus”. Hippocampus is a deep area within the temporal log, and in the short term there is something call a Pepez circuit, which we will talk about, the whole thing is transferred from hippo campus.

Once this neurons have established a connection to a wide spread area, wide spread area in the brain. So, there is no definite area in the brain where which you can say that memory is stored here, memory is a wide spread otherwise you know what will happen,

the brain will be over situated like you have 1000 neuron for rose, thousand for thon, thousand for color, thousand for it cannot happen.

So, is smell as to come out from the smell area vision has to come out from, so it is a wide spread long term memory which is spread, associative again. So, there may be thousand centers which will get activated when you think of rose, may be a memory with your spouse and your lover, but that will be a different area, the hippo campus is largely involved and that is the area which gets first them (Refer Time: 19:17) people is start losing memory in a illus call dementia, as long as dementia, the first sign of (Refer Slide Time: 19:24).

This dementia is a recent memory def set, and if lot of people who come to us they will say Purani bathe. They remember the old thing, they do not remember the new thing because the hippo campus is the place with the maximum damage is happening. So, this whole Hebbian learning is gone there the network gets them as.

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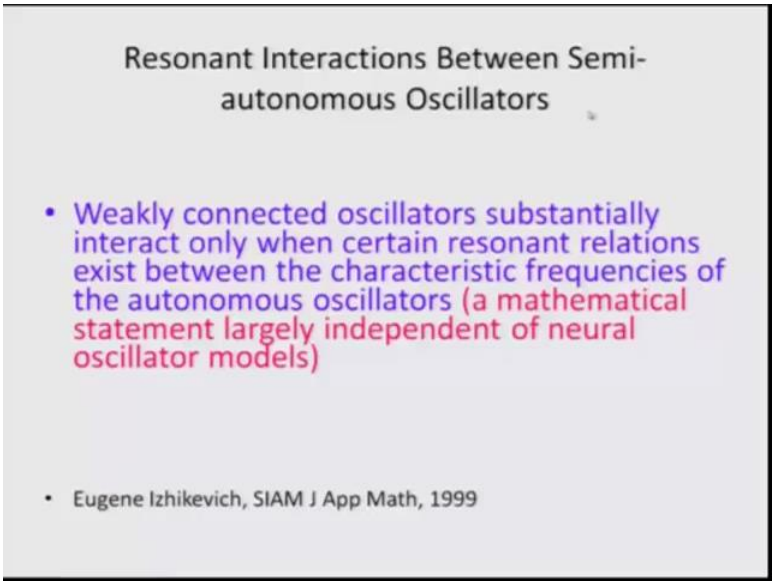

I also told you that, even if a noisy stimulus goes; the brain will still form a image. That is the Gestalt psychology, the gestalt people tell you; if you read them a brain uses lot of s matrix like closure, like approximation, like proximity to complete, brain does not want uncertainty and brain or human brain or any brain for the does not like ambiguity. So, if you give ambiguous signal, the brain will always try to form a certain thing I will look at

clouds, you will always see some images there, lot people see it, there smoke patterns you can see images, people see images wherever there is no image. So, that is the thing.

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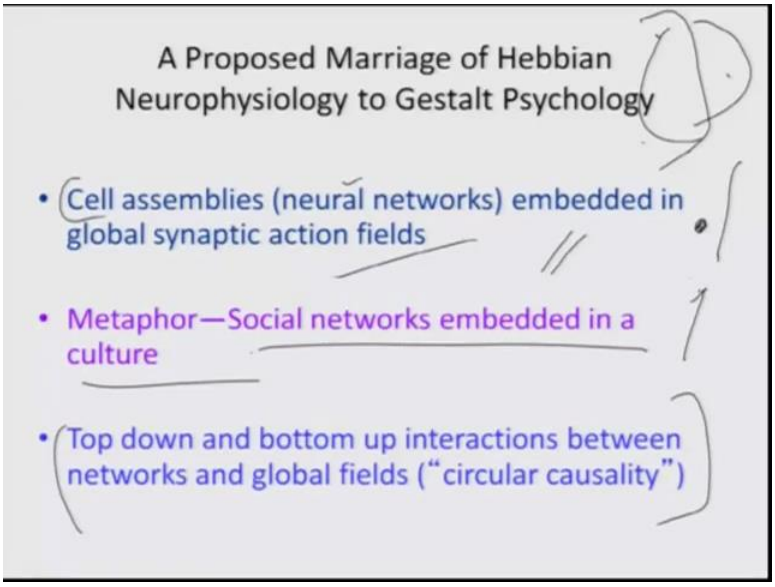

So, is it a marriage of Hebbian Neurophysiology with gestalt psychology - cell assemblies, so what was Hebb, saying Hebb was saying neurons, which fire together, fire together and. So, these neurons I met this huge network and what they form this columns and all there are functional cell assemblies. So, it is not one to one neuron, this is firing together.

For every stimulus and it is memory there are cell assemblies which will fire, which will try to create the full impression of the external thing, or may be internal stimulus, you can close your eyes and you can think about your last mill, you may still get the smell taste whatever. So, that is the memory which is gone it, but all cell assembly is which we are firing together at that time when you are eating that sumptuous meal, will be firing in reminding your things.

Now, in recall it may not be necessary that the all the piece anapestic and post anapestic will fire together in recall there is a copy of it in a different area. So, then recall only part of it me do, but while it is farming, the cell assemblies will go together and rest of the information it does not goes is all way done by. So, there embedded in global synaptic action field. Why global because there no set places from memory, they no boxes like

computer address, they are all content addressable, content addressable means, any part of that whole memory can trigger of the whole memory.

So, they have to be wide spread. So, also when I am saying it that pre synaptic; post synaptic it does not mean, they have to be in close vicinity, if it is 10 neurons, it may be firing together to bring out from memory and they can be widely separated. So, once cell assemblies, are widely separated this whole thing becomes global, if they are in close vicinity is local. So, they are embedded in this. Is like a social networks embedded in culture, we all live in India, we all are Indians, we have a common culture with minor variation here and there, but that my social network may vary from my apartments to my friends Indian friends living in New York, or Bangalore or Calcutta.

So, we say Hebbian cell assembly in know each other and if problem happens to me, all my friends will get activated all the time, they do not have to keep firing of being activated and no every mo minute of me, but there must have been a point of time; when we are firing together, otherwise how would I form a network with somebody who is living Australia.

So, there must have been a 6 months period, where I was we were doing everything together, that establish the memory and now something happens to me, then the whole thing will get activated; just say survival mechanism may be just as it is. So, this is we are embedded in the culture, but we our social network goes from this point to whatever is space time, geometry we are talking about and this global fields have a top down and bottom up. So, things can come from top they can go from down. So, this is the broad way of looking it.

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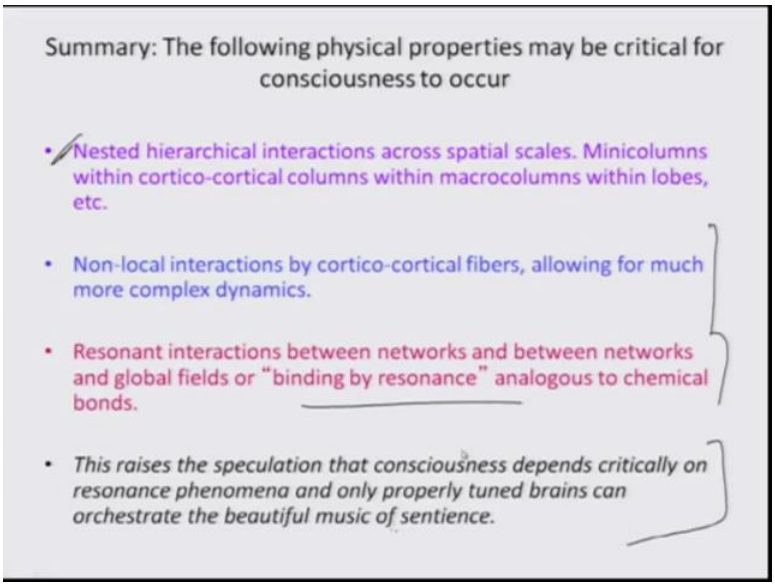

So, if you have to look at the summary, they are nested hierarchical interaction across spatial scale as I said, non local resonant interaction, resonance means keeps going in some of them may amplify another binding.

So, consciousness may critically depended on this phenomena, which is not our concerned at this point of time, we will talk about it as when we, it is all rap up this lecture here with this image, we have talked about networks an oscillation and you seen in Hopfield, then the way things, how will to have, we will come to memory again

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What is this? This is we must have we knowing this, this is the film, also very famous film Babel this, this is the mythological story; when god made human beings and the various species and it is said probably, they will troubling him too much.

So, he also knew which is a smart because is god. So, he created this tower of Babel and on each floor of it they were in habitants. So, together he knew that, they can create lot of (Refer Time: 25:59) case in life. So, he did a smart thing and his smart thing is they all had different language. So, 1 flour could not communicate to the other, this is a tower of Babel brain also if you look at it everything appears, different behavior a huge behavior people right from left to killing they do lot of thing, come down where is it arising from, they do differently, they are differently has individuals is small group, they and differently large groups, they are differently, countries we have differently, continents they have differently.

But base line behavior everything is coming from the brain, come down we have (Refer Time: 26:49) hemisphere, we would not see nothing, you open up a live rend we do not know, what to do on naked eye really do not know what is happening, then you have got technologies start looking at the electrical ways or you cut at that brain and you find lot of grossly you see chunks of these pieces. Then you go microscopy find neurons you will number of neurons you, you sit with all that what do you with, that a structure. So, structure does not mean anything to you

So, you go further device ways to look in to the activity, you find e g waves and now you have AMR you see some very brain area (Refer Time: 27:33) all that is direct indirect signals, again no meaning, then you go further bring not mathematical (Refer Time: 27:44) look at the guest of whether these neurons are connecting this way, which partially are proven with psychology, partially on proven, because you give ask you ask people to perform you guess this network is shown him by still to really differentiate between this networks.

These are really cannot verify it because it is fits in to theory, that is why it sounds sensible and this networks keep firing with the oscillation, electrical activity which you have take upon easy and how do they real, but still we do not know how do they really transmit, translate into behavior, may be firing what does it mean physically, yes may be, but may be you move your hand, you can seed on MRI or E or you can put it to the

computer do it, but beyond physicality, how does it think, how does it emote. These are big questions because, how does this electrical activity actually changes to thought action me. We will talk about it in the next lecture.

Thank you.