Cognition and its Computation
Prof. Rajlakshmi Guha
Rekhi Centre of Excellence for the Science of Happiness
Indian Institute of Technology, Kharagpur

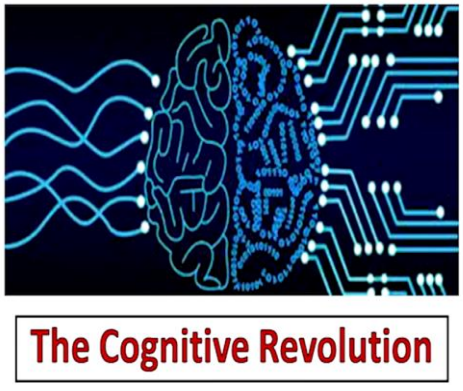
Lecture - 03
The Cognitive Revolution

In today's lecture we are going to continue with how cognition has the studies on cognition has developed over time. And, in the last lecture, we spoke about Egyptian times that we moved into the other civilizations around that period and how the heart was seemed to have gained more importance than the mind and its thought processes.

Later on we saw with the development in fact, even Aristotle thought that it was a mind it was a heart that was more important than the mind. And gradually we saw that from the renaissance thinkers like Da Vinci, Galen and so on people started thinking of the importance of the mind.

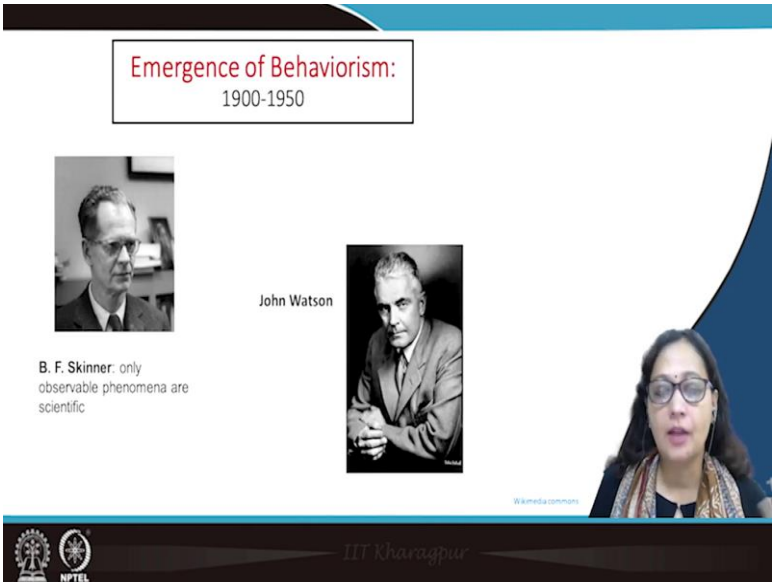
And, in fact, gradually there were areas in the anatomy that was identified as specific for the location or the of the functions of thought, emotions and other cognitive processes. We in this lecture we will gradually talk move into the scientific adaptations that have come forth or I should say the scientific progress that has come forth in the studies of cognition.

(Refer Slide Time: 01:48)



And this the period between the 70s to the 90s is known as the cognitive revolution period of cognitive revolution. In fact, it started way beyond or rather way before that earlier in the 48 with the Hixon symposium and then on there were several other symposiums where multiple disciplines came together to understand cognition. So, today we are going to talk about the psychological sciences, linguistics and computational sciences how all of it all the interdisciplinary sciences got together to understand cognition.

(Refer Slide Time: 02:41)



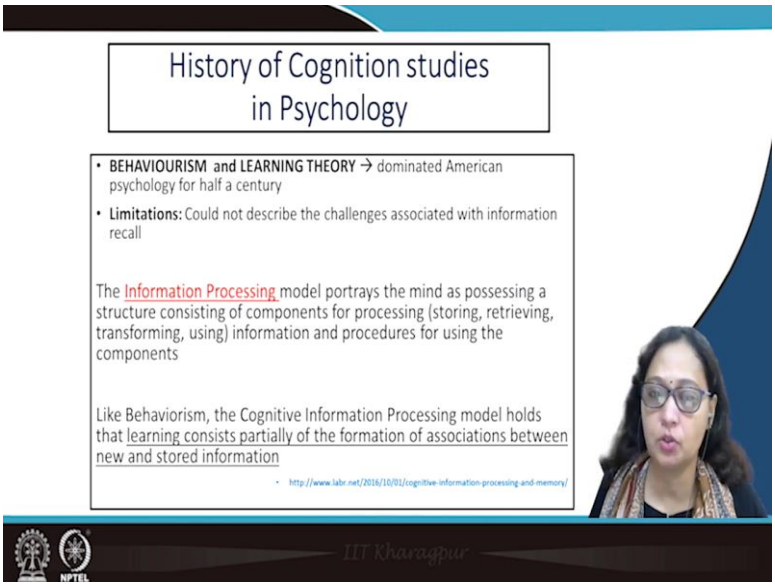
In the psychological sciences as you will see in the psychological sciences as you will see the eminent thinkers of psychology like Freud and (Refer Time: 02:47) had hoped to base their studies on the understanding on the neural basis of mental events. And, their efforts were unsuccessful because the structure and function of the human brain was not available to them for empirical study or other physiological level.

And from there emerged behaviorism the criticism because behaviorism studied observable behavior and this was a stark criticism of the structural and functional theories of psychology. And, we saw with behaviorism the observation of behavior was a significant phenomena and they thought that this was the scientific observation of what was going on within the individual.

And, this behaviorism had gained a stronghold between the years of 1900 and 1950, but gradually during the 50s and onwards there was a controversy an opposed oppositional

thought that was developing against behavior behaviorism too. One of the reasons for this is the growth of our knowledge about the human brain function with the advancement of physiology we also understood how the human brain functioning our knowledge about the human brain functioning expanded.

(Refer Slide Time: 04:10)



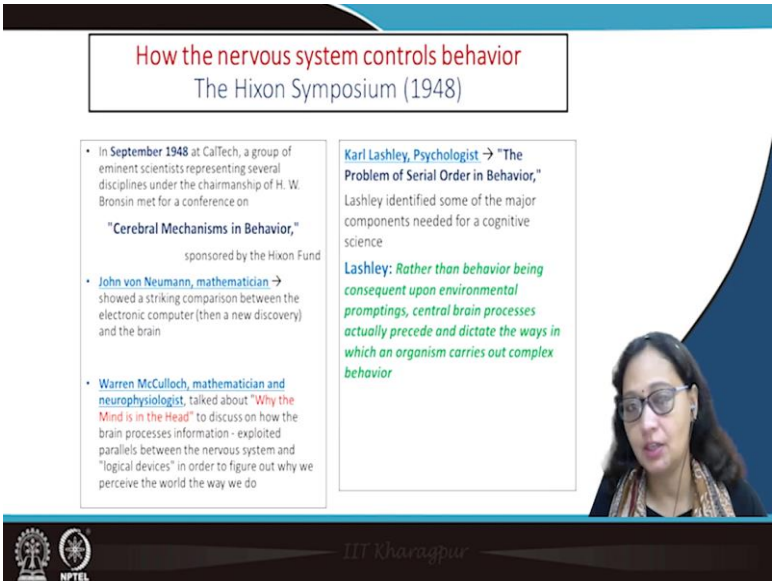
And, we realized that the study of behaviorism was like something into a black box. So, we did not really know what was going on within the individual, but we were just studying the observable phenomena outside. So, it was important if we were looking at the brain and anatomical features, it is it was important to understand what was going on within that black box.

So, the from here developed the studies of cognition and here the cognitive psychology it came into being. And, the information processing model at this point in or point in time gained a lot of prominence because it was talking about the specifically about storing, retrieval, transformational processes and was talking about the procedures for using these components.

The like behaviorism, the Cognitive Information Processing model was holds that learning consists partially of the information of associations between new and stored information. So, it was moving away from behaviorism, but it was also having some kind of a lineage from the behavioralistic school. Gradually so, in as I was mentioning at the

start the there was a development of interest in other scientific fields of study and the Hixon Symposium is a stark evidence is a weakness of these developments.

(Refer Slide Time: 06:03)

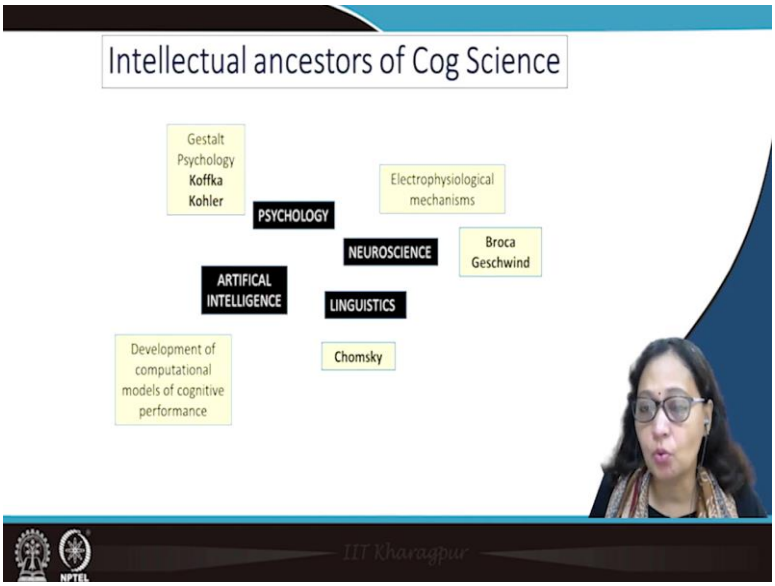


The Hixon symposium took place at CalTech in 1948 September of 1948 and they were under the chairmanship of H. W. Bronsin and the theme of the primary theme of the conference was Cerebral Mechanisms in Behavior. So, you see this is an extension from the behavioral school where you know they were trying to people were trying to explain behavior through anatomy and along with.

So, Lashley was one of the you know proponents of behaviorism who also wanted. So, to identify some explanatory ideas about cognition and Lashley was one of the members of this symposium. Along with this, we saw Neumann who was a mathematician who had the discussions discussed his views on the comparison of the electronic computer at that point time point in time a new discovery and the brain.

We also saw in this symposium Warren McCulloch, a mathematician and neurophysiologist who spoke about Why the Mind is in the Head that was the title of his talk and he discussed about the brain processes of information, and he exploit the parallels between the brain and the logical devices or machines like the computer.

(Refer Slide Time: 07:54)



So, there was as you can see there was developing an interest from multiple disciplines in science to understand cognition and its processes. And, the intellectual the this was as I said that this was developing into a new science of cognitive a new science of cognition, and the intellectual ancestors were from multiple fields of Gestalt psychology who spoke about insightful learning, who spoke about processes like problem solving and they wanted to understand the mechanisms beyond explainable behavior.

And, here there was the development of neuroscience where you already have heard about Broca and Geschwind and understanding electrophysiological mechanisms, they tried to see along with other neuroscience people at that point in time. It was more like physiology who were trying to understand physiologists who were trying to understand the electron electrophysiological mechanisms that lead to different kinds of thoughts and mental processes.

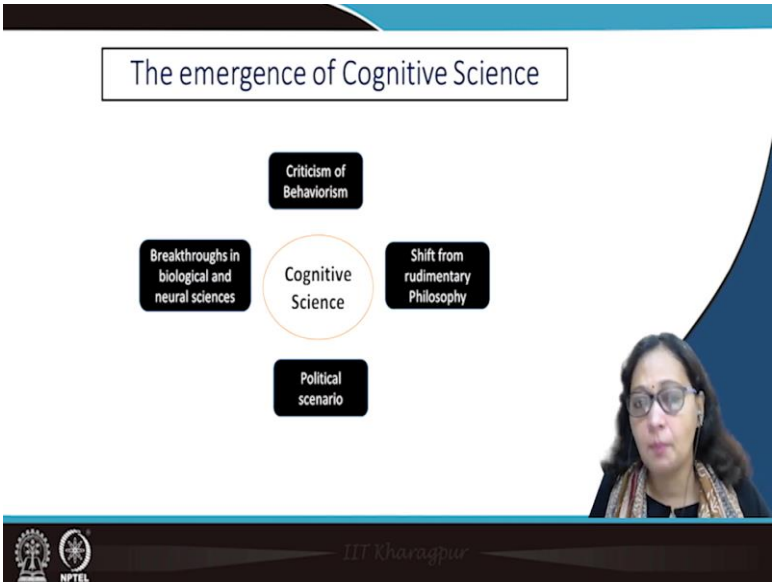
And, we had people from artificial intelligence that was also a new field as an extension of computational sciences who wanted to understand the similes or the who wanted to study the differences and the similarities between a machine and a brain. So, in fact, from this time onwards the analogies of the brain model were drawn from computational sciences.

As many of you who are familiar with the Atkinson – Shiffrin model you will realize that it is quite like talking about the a computer machine with the RAM and the ROM. And,

in fact, such analogies were drawn in other explanations of the anatomical processes as well.

And finally, Chomsky Noam Chomsky bore the flag for linguistics. So, he showed that how language and thought are highly correlated. Later on was because we have a lot of other people who were interested in language and science and classical names to mention is Anderson and Nancy Anderson who worked in language and thought and later on into creativity.

(Refer Slide Time: 10:44)



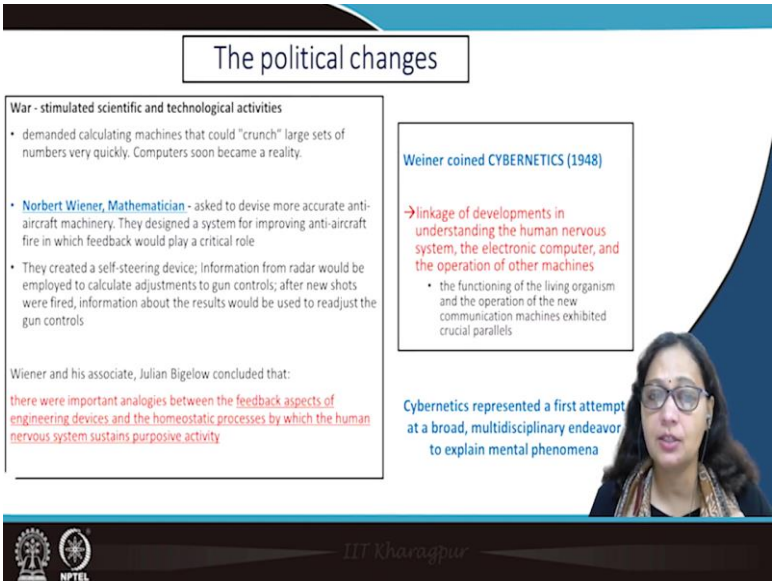
So, these disciplines were actually the intellectual ancestors of cognitive science and then finally, the emergence of cognitive science. And, the primary reasons for the emergence of cognitive science was the criticism of behaviorism as we already spoke of it – a shift from rudimentary philosophy so, the study of the soul from the study of the soul to the mind to finding scientific explanations of behavior.

And, the breakthrough in the biological neural sciences with the development of most of the instruments to understand to see single units of behavior so, the electron microscope, the electrophysiological units we were this helped with the advances of understanding thought.

And, the most significant part is the political scenario. So, we had two wars the in between and during the war there were many scientists who were asked to develop

machinery with feedback systems. And, Norbert Wiener, a mathematician, was one of them and he was asked to devise an accurate anti-craft machinery.

(Refer Slide Time: 11:49)



And, the system was to be you know improving on itself with feedback from the previous shot. So, Wiener and his associate Bigelow they created a self steering device and information from the radar would be employed to calculate adjustments to gun controls.

And, this is along with the you know the machinery there was developing they were developing some insights into the understanding of the human nervous system and they drew the important analogies between the feedback aspects of engineering device devices and the homeostatic imbalancing processes of the human nervous system.

And along with this so, Wiener coined the term cybernetics that is the linkage of developments in the understanding of human nervous system the electronic computer and the operation of other devices. The development of cybernetics in the year 1948 is very crucial to the development of cognition cognitive studies and cognitive science.

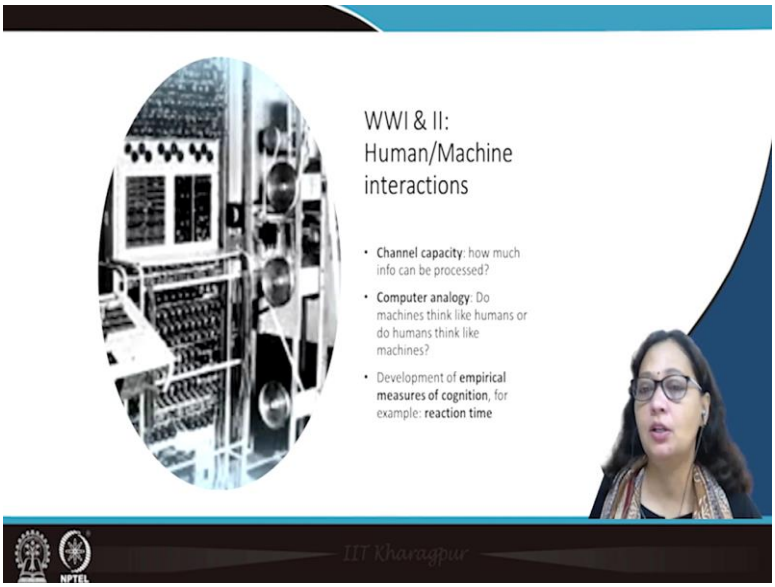
The reason is that this was a first attempt at a broad multi disciplinary endeavor to understand mental phenomena. As I mentioned the seat was being created by different disciplines discussing amongst themselves discussing with each other about the

mechanisms and of the brain, of the mind with analogies drawn from their personal researches.

And, so, the development of cybernetics set a grand foothold to further developments in cognition. Another change or rather another development during the war wars was developing machines that could crunch large set of numbers and the computer again became a reality at this point in time.

So, we know how the role of the computer in the understanding are of cognitive sciences I would rather say that the explanations of behavior cognition and behavior through computational mechanisms gained the foothold later more much later through AI. And, in fact, today there are a lot of studies on AI where we are trying to understand and replicate human behavior human thought processes.

(Refer Slide Time: 14:51)

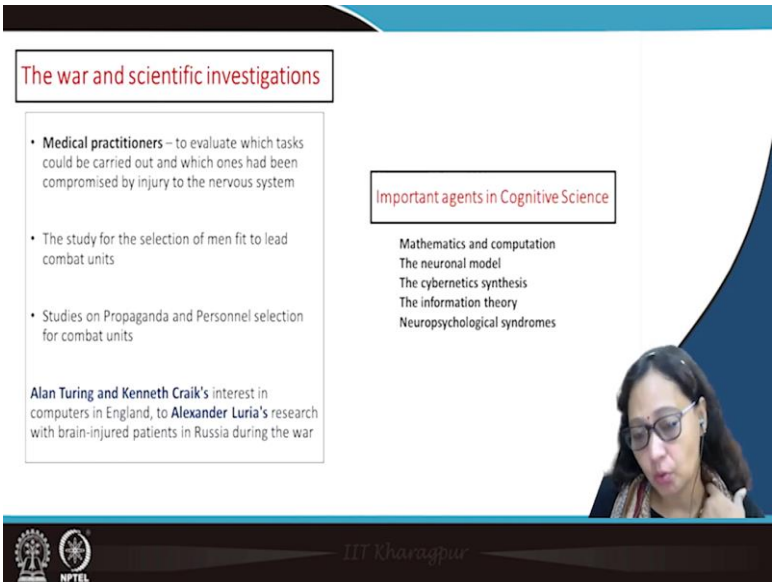


So, this the World War I and II where human machine interactions became an essential and some of the questions that had come over from during this period was what is the channel capacity so, in case of a machine, in case of the human brain so, or the human process information processing system?

And, the one of the thoughts that developed during this time was do machines think like humans or do humans think like machines. Earlier AI actually addressed these problems; later on AI changed its ways and developed into you know looked into other things. So,

the development of empirical measures of cognition in this time the studies of reaction time you know were started initiated. And, along with the these developments in machines there was the medical practitioners who added to the knowledge of cognition. How?

(Refer Slide Time: 15:48)

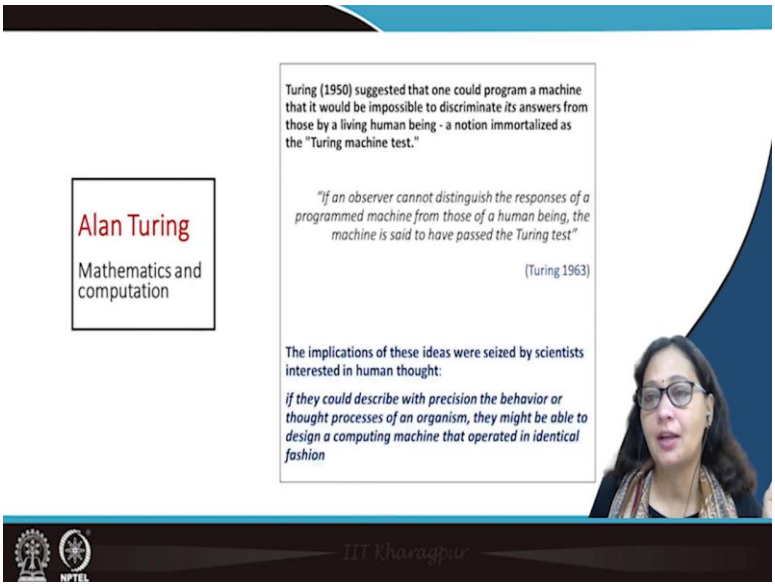


So, they were seeing a lot of neuropsychological syndromes and injuries, head injuries during the war and one classic example of work during this time is by Alexander Luria with brain injured patients in Russia during the war. Till date the Luria Nebraska cognitive test battery is used to understand several neuropsychological syndromes.

So, it was a huge study. It showed a lot of in fact, intelligent studies during the war also gained a strong foothold, as to how that many intelligence tests were developed during this period, as to understand how the individual to assess the individuals intellectual capacity whether they were able to what they were whether they were fit mentally fit to participate in the war to take instructions.

So, the group test of intelligence in fact, developed during the wars. So, and studies of propaganda and personal selection for combat units – these also develop. We need to when we talk of cognition and cognitive studies we especially for cognitive science we cannot do away without with Turing.

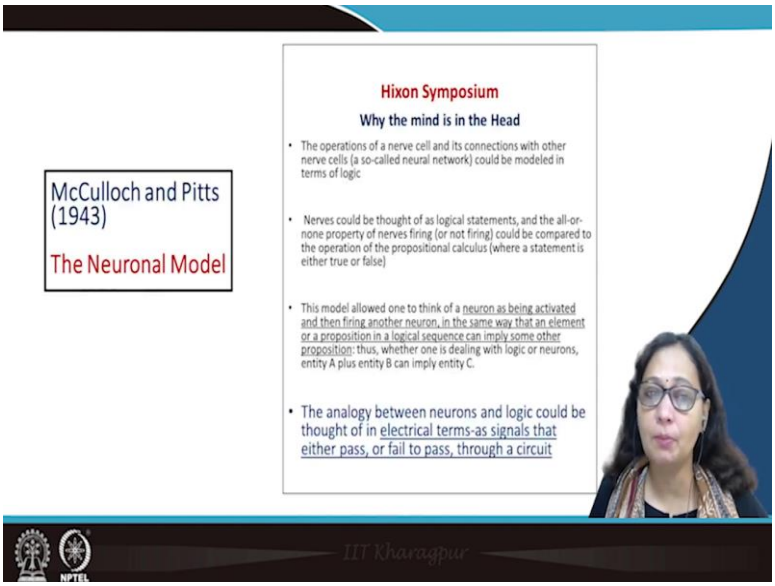
(Refer Slide Time: 17:28)



So, Alan Turing a mathematics and computational researcher in the 1950 suggested that a program one could program a machine that it would be impossible to discriminate between a human and a computer and this has been immortalized as a Turing machine test.

And, he to quote Turing, if an observer cannot distinguish the responses of a program machine from those of a human being the machine is said to have passed the Turing test. So, this has an implication you know into human thought and this interested the scientists. So, if they could describe with precision the behavior or thought process of an organism they might be able to design computing a machine that operated in identical fashion.

(Refer Slide Time: 18:26)



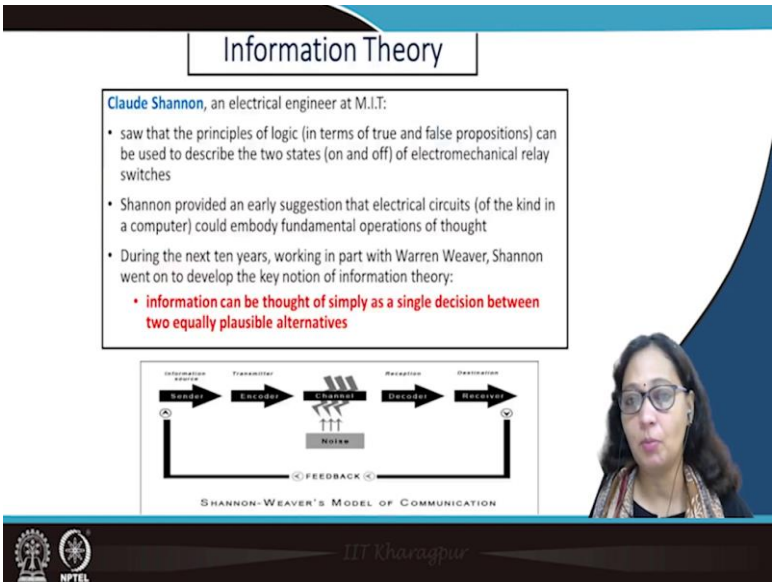
Now, this led to further studies in computation and in AI. The in the Hixon symposium as I mentioned Mcculloch and Pitts they spoke about their neuronal model. They had come up with this model of a single nerve cell and its connections with other nerve cells and they spoke about the neural connection.

And, they followed the they showed the Donald Hebbs theory the discussed about the Donald Hebbs and Donald Hebbs theory where they explained that the a neurons is its behavior is like a logical sequence. So, it is you know whether when you deal with neurons it is quite like dealing with logic. So, entity A plus entity B can imply entity C.

So, he McCulloch and Pitts they drew an analogy between neurons and logic and they said that these signals were quite binary from the neuron, it was binary. So, it could be explained through electrical term terms as signals that either pass or fail to pass through a circuit.

And, in fact, this theory has a very very significant role in the studying of the neuronal function. So, from a single neuron to understanding neural networks, the neuronal model was the initiation of such thoughts.

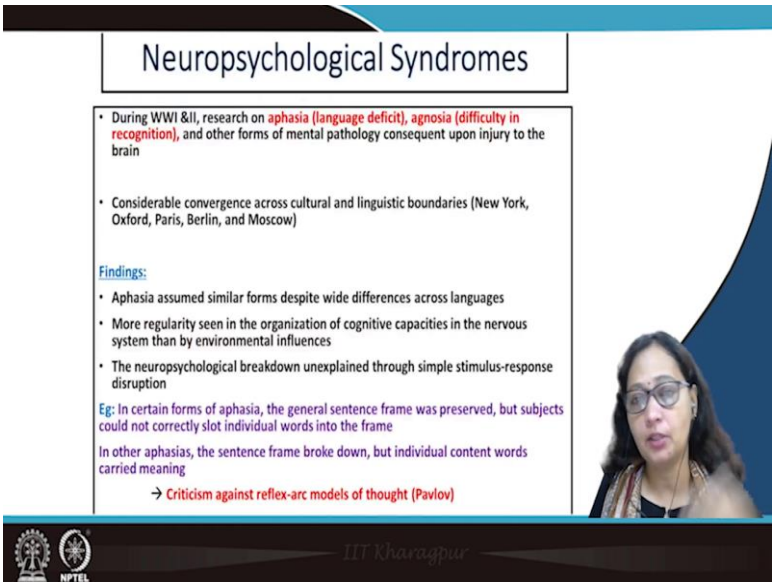
(Refer Slide Time: 20:06)



Shannon Claude Shannon during this time came up with the information theory and he explained that information can be thought of simply as a single decision between two equally plausible alternatives. So, if you look at this, at this point in time what is happening between the 40s and 50s? So, people are trying to explain the passing of information from one unit to the other.

And, with the development of medical sciences, with the development of instrumentation people were trying to understand the processing of behavior at a single unit level. Now, my colleague later on will talk to you further about how information is processed from a single unit or a single neuron, and that is how he is going to explain computational mechanisms of cognition.

(Refer Slide Time: 21:06)



So, I spoke about neuropsychological symptoms coming back to it again along with Alexander with Luria's work here there were other researches that were being conducted on language deficits and agnosia that is difficulty in recognition due to some pathology. So, this pathology could be head injuries, these pathologies could be the shock due to a bombing and several other injuries.

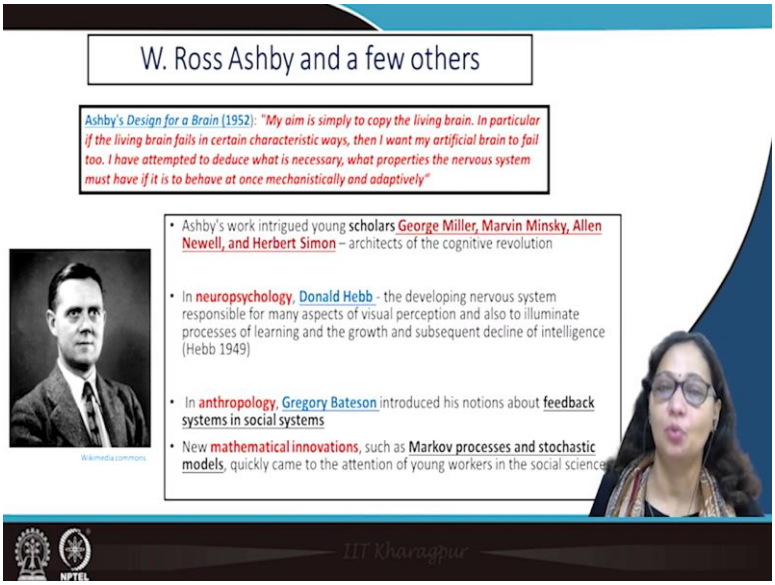
And, here there was a considerable convergence irrespective of cultural and linguistic boundaries. So, people studying language deficits in Russia or Paris or Berlin or Oxford or New York found that aphasia or language deficit assumes similar forms despite differences in languages. So, this just showed that language it is not the language that is a cause of the deficit, but it must be somewhere ingrained within the brain. So, it must be somewhere ingrained with a linkage to information processing system.

So, that is why you know linguistics later on became a very very important contributor to the cognitive sciences. And, so, more regularity was also seen in the organization of cognitive capacities than by environmental influences. So, the nature nurture problem that again came into being. So, how important was nature rather than the environmental influences on the cognitive capacities.

And, the they were trying to explain neuropsychological breakdown you know which could not be in different ways because in other ways because the simple stimulus

response mechanism was not enough to understand the neuropsychiatric symptoms that had developed that they were getting to see during the wars.

(Refer Slide Time: 23:33)



So, we move from the from Luria and others during the time from Noam Chomsky to Ashby and a few others and Ashby at this time was talking of the design of a brain.

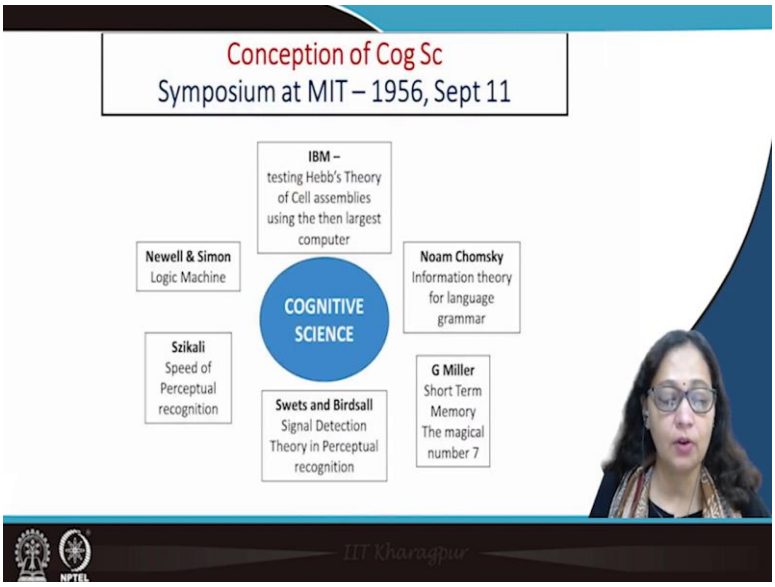
So, what Ashby's work actually was to copy the living brain and he to quote Ashby – In particular if the living brain fails in certain characteristic ways then I want my artificial brain to fail too. I have attempted to deduce what is necessary what properties the nervous system must have if it is to behave at once mechanistically and adaptively.

Now, this intrigued multiple scholars like Miller who was a psychologist, Minsky, Allen Newell, Herbert Simon and these people were from different fields and they got into the talking about the an explanation of cognition mechanistically and they are in fact, the architects of the cognitive revolution.

In neuropsychology, Donald Hebb again was speaking I spoke about him earlier, he was speaking about the developing neural system and how visual perception many aspects of visual perception to explain you know processes of learning and intelligence. And, Bateson in anthropology during the same time was talking about feedbacks feedback systems and social systems and other Markov was talking about you know sorry new mathematical innovations like Markov processes and stochastic models came into being.

Of course, the Markov processes did not hit well with researchers in the neurosciences because they were not able to explain everything through the metal phenomena with the Markov processes. Now, as you see this set for the set the field for the development of the a new concept of cognitive science.

(Refer Slide Time: 26:01)

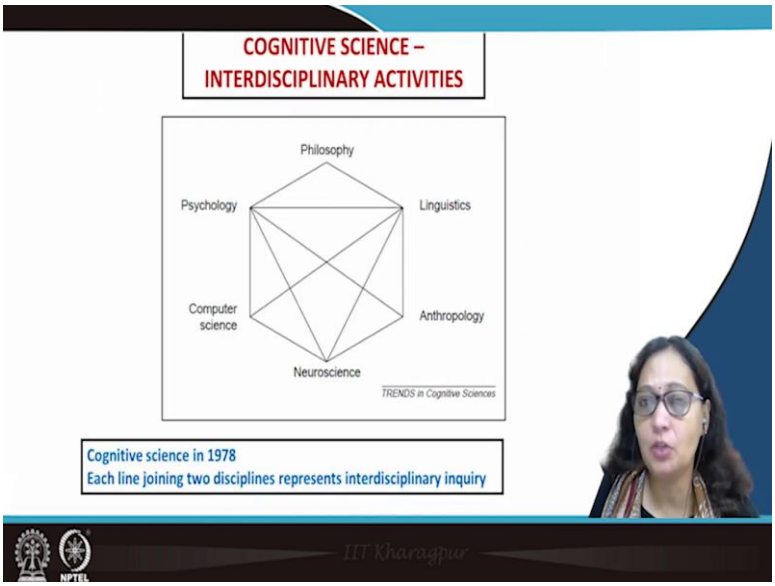


And, from the Hixon symposium that happened between 48, September, 48 to 56 all these developments transdisciplinary interactions were taking place. And, at MIT in 1956 we had the symposium for the development of you know a new science that is where it emerged as a new science.

And, there were multiple people of most I have already spoken about they talked about they had their discourses on different aspects. So, there was Newell and Simon talking about the logical logic machine; Chomsky about the information theory for language grammar; George Miller spoke about short term memory and the magical number 7 and Szikali he was working on perceptual recognition and he spoke about the speed of perceptual recognition.

There were Swets and Birdsall who spoke about signal detection and perceptual recognition and finally, IBM they tested Hebbs theory of self assemblies using their then largest computer.

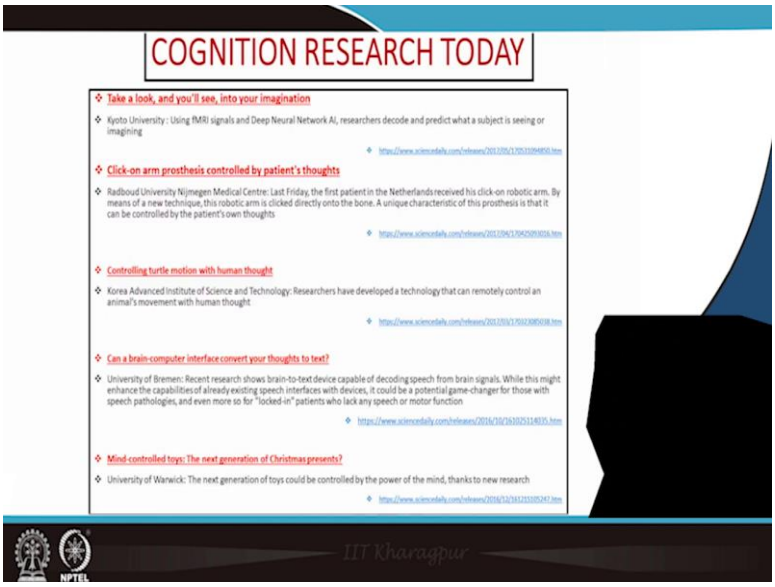
(Refer Slide Time: 27:26)



So, this you see we have people from all fields coming together into the understanding of cognition and the fields were of philosophy, linguistics, psychology, computer science, neuroscience. And, in neuroscience Gazzaniga was taking a very very important part in creating a branch of neuroscience called cognitive neuroscience, along with it anthropology.

So, we have multiple interdisciplinary activities across this time to understand cognition.

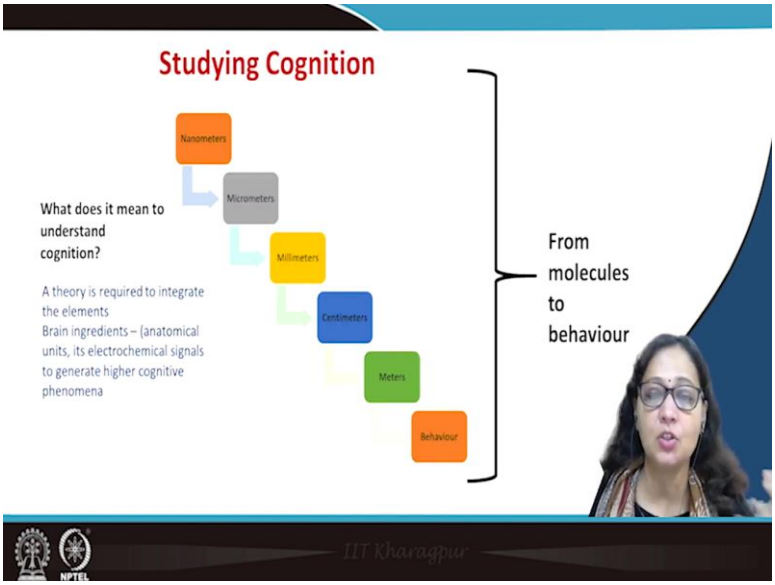
(Refer Slide Time: 28:01)



So, cognition research today has developed gone much ahead from the times of the Egyptians to the world wars to the renaissance to the world wars and now. And, these are some of the researches that are going on. Of course, you have multiple projects today to understand the human brain to understand cognition that are being carried out it at different labs across the world.

The approach to cognition cognitive studies has traveled from philosophy to technology and it is you know the it is if you are talking about studying cognition it moves from an understanding from the nanometers to micrometers in the study of the brain to millimeters, to you know a larger area of the brain to you know anatomical structures in the brain to behavior.

(Refer Slide Time: 28:54)



Now, these each individual units so, to study from the functioning of a single neuron to a network, to us a process to an anatomical structure and finally, to behavior is to understand more of the higher cognitive phenomena. So, we are when we talk of studying cognition it can be from molecules to behavior.

So, it need not we need to understand that cognition studying cognition is not only about studying, the learning, attention, memory, perception, processes, but also to understand how this happens in the nanometer units. So, here and how these circuitry are formed.

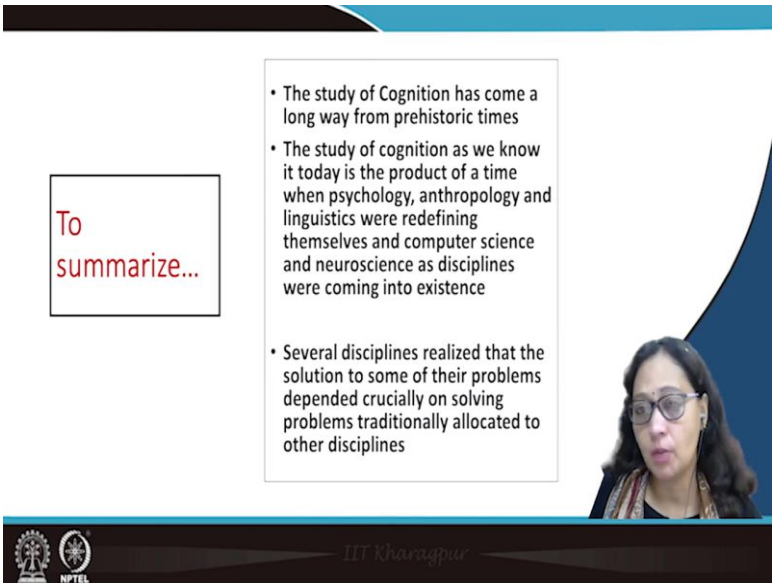
So, approach to cognition and of course, there are disciplinary different disciplines trying to explain cognition. So, the circuitry can be explained from the perceptions from the information gained from the neuroscientists. It can also be a model in the form of a model that came up from the computer scientists and the ai people.

So, there are different ways what I am trying to get at is studying cognition is can be from different angles it is like looking at the same phenomena from different angles trying to understand it better. But, what is required is to integrate these elements is to integrate these elements and one look forward is to see how we can understand each if you take a function a mental process to understand this each mental process from the nanometer unit to the behavioral unit.

And, why to the behavioral unit? To understand the disorders that happen in behavior. So, if there is an error in the if there is a delusion or if there is a perceptual error or hallucination then how can you study it or rather how can you explain it on all these parameters starting from the behavior going back to whether there are changes or whether there are any alterations in the nanometer unit from a in a on a single molecule unit.

So, this is how studies in cognition have progress.

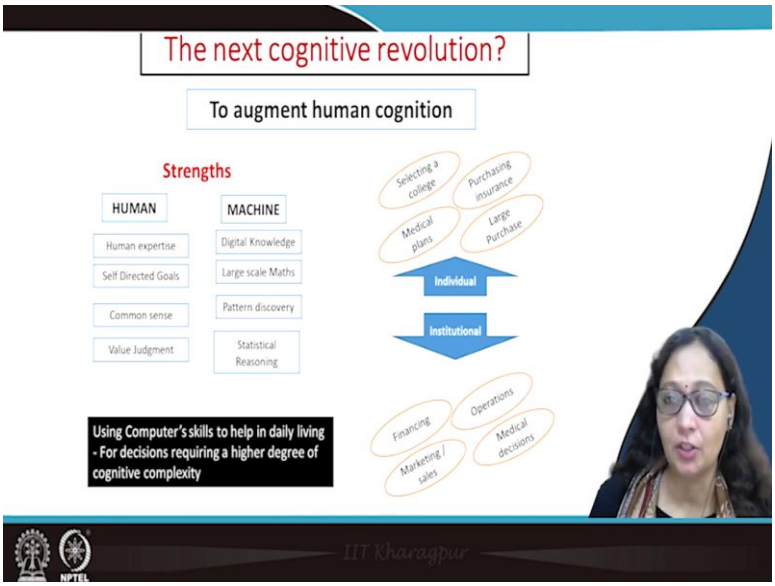
(Refer Slide Time: 31:59)



And, to summarize we have come a long way from the prehistoric times. It is today cognition is not reigned by psychology or philosophy, but it has redefined itself into you know an explanation from different bodies of science and different disciplines have come into existence and several disciplines have realized that the solution to some of their problems, depends crucially on solving the problems traditionally allocated to other disciplines.

So, it is not just restricted. Like all other branches of science we have understood this is an emerging thought that it is not a byproduct of a single discipline or a single vertical. So, the it is that is the a sense of interdisciplinary mechanisms.

(Refer Slide Time: 33:02)



And, looking at the next cognitive revolution what would that be about. So, an idea is perhaps you know it will be to augment human cognition.

We know the strengths of the human, we know the strengths of the machine and we are evolving daily to understand it better. So, can we use these skills to increase, to enhance human expertise? We have talked about behavior from the disorders perspective. So, that is to identify what would be the how to explain the limitations and how to help deal with those limitations psychopathologies in behavior.

But, how do we so, the perhaps the next cognitive revolution with the development of the positive psychology and other disciplines in science perhaps it would be to augment

human cognition. So, using machines to help in daily living and we have already started doing that.

Now, what more, how more could the machine help with the improvement on the augmentation of human cognition. So, that is about it for today and in the next class, we will talk more about the anatomical structures that are the in the brain I will specifically talk about the brain and this that are the seeds of cognition and the mental processes.

So, thank you.