Opinion and Perspectives

Why the Concept of "Quantum Brain" was not Discovered in 1940s

Erol Başar

Abstract

Already in 1940s several neurophysiologic, biochemical and physical discoveries took place and the conjecture was open for the initiation of the "Quantum Brain Concept". The present essay explains the ensemble of discoveries that could lead to the quantum brain concept and tries to find out the reason, why this concept was delayed during many decades.

Key Words: EEG, quantum brain

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Introduction

The *International Solvay Institutes for Physics and Chemistry*, located in Brussels, were founded by the Belgian industrialist Ernest Solvay in 1912, following the historic invitation-only 1911 *Conseil Solvay*, the first world physics conference. The Institutes coordinated conferences, workshops, seminars, and colloquia. In 1903, he founded the *Solvay Business School*, also at the University of Brussels. Finally, in 1911, he established the prestigious meetings of top scientists known as *Solvay Conferences*. The first and the fifth of these (1911 and 1927) are particularly noteworthy, as they helped define the foundations for the first and second incarnations of quantum theory.

Possibly the most famous conference was the October 1927 Fifth Solvay International Conference on *Electrons and Photons*, where the world's most notable physicists met to discuss the newly formulated quantum theory. The leading figures were Albert Einstein and Niels Bohr. Seventeen of the twenty-nine attendees were or became Nobel Prize winners, including Marie Curie, who alone among them had won Nobel Prizes in two separate scientific disciplines.

The first half of the 20th century has been reach in discoveries in the field of neuroscience as in the field of physics. Ramon y Cajal, Hans Berger, Otto Loewi, Charles Sherrington.

Neuron Doctrine was proposed by Cajal, Golgi, and Sherrington. Oscillations were first launched by H. Berger and Lord Adrian, Memory was studied by Henri Bergson, Hayek and Donald Hebb.

In despite of several fundamental discoveries new mathematical frameworks as Cybernetics the "*Quantum Brain*" could not be discovered at that time. However scientific fundamentals for that step were ready. We will describe fundaments and scientists for the possibility of discovering quantum brain in the following.

Corresponding author: Erol başar
Address: Brain Dynamics, Cognition and Complex Systems Research Center, Istanbul Kültür University, Istanbul-TURKEY
e-mail: e.basar@iku.edu.tr
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1. Norbert Wiener and cybernetics

Cybernetics is the science of control and communication, that is the transmission, exchange and processing of signals in animals and in machines. Although Wiener's formulation was based on very little experience in biology, it predicted the course of the development of research in the field of *cybernetics*. His definition includes everything that the term *cybernetics encompasses* today. Although several research scientists find Wiener's approach somewhat old fashioned the intellectual impact of his had a strong influence on several disciplines and also provided a turning point for the establishment of schools of Ilya Prigogine on "*Dissipative structures*" and school of Herman Haken in "*Synergetics*". The view of René Thom in "*Catastrophe Theory*" and also the general nonlinear approach to sciences have immensely profited from Wiener's vision. The book provided an inspiring framework for thinking broadly in parallel in multidisciplinary fields. One thing is absolutely clear, that the research leading to the foundation of "*Brain Dynamics*[2]" was anchored to the idea of signal processing and communication in the brain.

In the introduction to "*Cybernetics*" Wiener gives a detailed description of the experiences and thoughts that preceded the founding of *cybernetics*: On the basis of reflections and of conversations with scientists in many specialties especially with physicians, it became clear to him, as a mathematician, that control processes take place and that information is transmitted and stored in the human organism as well as machines (Hassenstein, 1971). Wiener advised scientists working in multidisciplinary areas that although a physiologist, working with a mathematician, will be never able to develop as powerful mathematical techniques as that mathematician would do, but, the physiologist will at least be able to develop the skill of understanding the mathematical tools they are jointly applying. Similarly, a mathematician or physicists will never be able to develop a physiological preparation with the skill of a biologist. However, they can understand what is going on in the physiological system and the main propose in investigating a given function. [3]

Wiener discovered functional similarities between technical processes and living organisms. The new science of *cybernetics* was intended to create a scientific framework considering it as a separate branch of science with the idea of conforming to the functional principles in technology and biology. *Cybernetics* was conceived as a common ground on which engineers, biologists, mathematicians, psychologists, etc, could meet and discuss in a common scientific language the problems of control and communication that appear in various forms in their scientific fields.

This means that the concepts of *cybernetics* should be neutral and abstract; they should contain no specifically technological or biological characteristics that would make them inapplicable to another field. By considering these entire essential proposals it can be seen that the science created by Wiener was a "*school of thought*", unique, at the beginning of the twentieth century and resembling the Ancient Greek Academy of Athens. However, the philosophers of Athens and later of Ionia did not have the tools available to Wiener. Unfortunately, Wiener's life was too short for him to realize his applications in biological sciences; however, despite this his predictions of the future governing role of computers have come true. The applications of cybernetics are detailed elsewhere in this book (See especially chapters 3 and 6).

2. Henri Bergson

Henri Bergson was one of the leading philosophers in the 20th century. *Duration, memory, Élan Vital* mark the major stages of Bergson's philosophy. *Intuition* is the method of Bergsonism. Intuition is neither a feeling, an inspiration, nor a disorderly sympathy, but one of the most fully developed methods in philosophy. It has strict rules constituting that which Bergson calls "*precision*" in philosophy. Bergson emphasized that; intuition, in his understanding, methodologically, already presupposes *duration*. "These conclusions on the subject of duration were decisive. Step

[2] W.J. Freeman 1975, Başar 1976, Başar 1980

by step they led me to raise intuition to the level of philosophical method" (Deleuse, 1966).

Bergson relied on the intuitive method to establish philosophy as an absolutely "precise" discipline, as precise in its field, as capable of being prolonged and transmitted as science itself. Further, without the methodical thread of intuition, the relationships between *Duration, Memory and Élan Vital* would themselves remain indeterminate from the point of view of knowledge.

The most general methodological question is this; how is intuition, which primarily denotes an immediate knowledge (*connaissance*), capable of forming a method, once it is accepted that method essentially involves one or several mediations? Bergson frequently presents intuition as a simple act. But, in this view, simplicity does not exclude a qualitative and virtual multiplicity, the various directions in which it comes to be actualized.

Bergson considered that he had made metaphysics a rigorous discipline, one capable of being continued along new paths which constantly appear in the world. Below is a short commentary on the history of the Bergsonian philosophy:

> As a mathematic genius and concrete scientist Bergson introduced considerable important concepts to the cutting edges of natural-philosophy. His popularity declined for various reasons one being the criticisms made by the British philosopher Bertrand Russell, who was, contrary to Bergson an elegant politically oriented social philosopher. The French philosopher Deleuze wrote a most important book on "Bergsonism" and started a Renaissance of Bergson's Ideas.

Intuition

Bergson saw intuition not as an appeal to the ineffable, a participation in a feeling or a lived identification, but as a true method. This method sets out, firstly, to determine the conditions of problems, that is to say, to expose false problems or wrongly posed questions, and to discover the variables under which a given problem must be stated as such.

Bergson defined duration as a multiplicity, a type of multiplicity. This is strange word, since it makes the multiple no longer adjective but a genuine noun. Intuition is seen as method, philosophy as rigorous science and the new logic as theory of multiplicities. Bergson invokes metaphysics to show how a memory is not constituted after present perception, but it is strictly contemporaneous with it, since at each instant duration divides into two simultaneous tendencies, one of which goes toward the future and the other falls back into the past.

According to Bergson new ideas in science always appear strange at first but these are precisely the ideas that may be the most fruitful, Bergson insists, they may well ideas engendered by philosophical intuition. Accordingly he stated:

> "I take the view that several of the great discoveries, of those, at least, which have transformed the positive sciences or created new ones, have been so many soundings in the depths of pure duration. The more living was the reality touched, the more profound had been the sounding."

Really important intuitions are by nature rare events. The point is that Galileo's', Newton's and Leibniz's treatments of motion are the absolutely essential turning point of history in science. Modern science could not be realized without them. Bergson believed the intuition's leading to such discoveries have been achieved only haphazardly, but it is now possible, to search for them methodically.

In his *'Évolution créatrice* (1907) [*Creative Evolution*], Henri Bergson declared that the most lasting and most fruitful of all philosophical systems are those which originate in intuition. If one believes these words, it appears immediately with regard to Bergson's system how he has made fruitful the intuitive discovery that opens the gate to the world of his thought.

What we usually call time, which is measured by the movement of a clock or the revolutions of the sun, is something quite different. It is only a form created by and for the mind and action. At the end of a most subtle analysis, Bergson concluded that it is nothing but an application of the form of space. Mathematical precision, certitude, and limitation prevail in its domain; cause is distinguished from effect and hence, raises that edifice, a creation of the mind, whose intelligence has encircled the world, raising a wall around the most intimate aspirations of our minds toward freedom. These aspirations find satisfaction in «living time»: cause and effect, here, are fused; nothing can be foreseen with certainty. (See chapters 15-19, for the Cartesian system in probabilistic hyperspace) for certainty resides in the act, simple in itself, and can be established only by this act. Living time is the realm of free choice and new creations, the realm in which something is produced only once and is never repeated in quite the same manner.

According to Bergson imagination and intuition are sometimes capable of flights where intelligence lags behind. It is not always possible to decide whether the imagination is seduced or whether the intuition recognizes itself and allows itself to be convinced. In any event, reading Bergson is always highly rewarding. In the account of his doctrine *Évolution créatrice*, Bergson created a concept of striking grandeur, a cosmogony of great scope and unflagging power, without sacrificing a strictly scientific terminology. It may be difficult at times to profit from its penetrating analysis or from the profundity of its thought; but one always derives from it, without any difficulty, a strong aesthetic impression (Deleuze, 1966).

Possibly, one can apply to this intuition, the central point of the Bergsonian doctrine, the brilliant expression that he uses about intelligence and instinct: the perilous way toward vaster possibilities. Within the limits of its knowledge, intelligence possesses logical certainty, but intuition, dynamic like everything that belongs to living time, must, without doubt, content itself with the intensity of its certainty. This is the drama: creative evolution is disclosed, and man finds himself thrust on stage by the *élan vital* of universal life which pushes him irresistibly to act, once he has come to the knowledge of his own freedom, capable of divining and glimpsing the endless route that has been traveled with the perspective of a boundless field opening onto other paths. Which of these paths is man going to follow?

Einstein's Theory of Relativity and in Quantum Dynamics is completely different from classical physics of Newton. Things are completely changed in the physics of the 20th century. In the search of Brain-mind we are still far away from including this transcendent view. However, some new steps can be seen on the horizon. In his recent work of Kelso (2006) offers an ambitious and much needed: analysis of the "complementarity" concept of Niels Bohr within an extended physical-psychological-philosophical framework.. The necessity of new frameworks, including a Cartesian one, is contained within a very interesting book by Fritjof Kapra "The Turning Point" (1982).

3. Sigmund Freud and Carl G. Jung

A. Sigmund Freud and Unconscient

The theories of Sigmund Freud have been in the last years again a focus point among several neuroscientists. As initiators of this new stream we firstly mention Mark Solms and Eric Kandel. The modern view of the scope of Sigmund Freud is described mainly by Mark Solms and in the following we will shortly summarize the modern interpretation of Freud's hypothesis. Freud's theory of the mind was based on the concept of the human organism as a complex biological machine. According to Freud psychological processes were deeply rooted in the bodies physiology and biochemistry and followed the principles of Newtonian mechanics (This means it is not probabilistic). Mental life in health and illness reflected the interplay of instinctual forces within in the organism and their clashes with the external world. In the present book, we also search the roots of the "mind" also in physiological and biochemical mechanisms in also deeper brain structures as the brain stem. However, in our approach we also introduce physical concepts and also mathematical tools for the interpretation of the empirical results.

The most significant contribution Freud made to the neuroscience was his argument for the *existence of an unconscious mind*. During the nineteenth century the dominant trend in western science was positivism. Freud, however, proposed the concept of unconscious by assuming that awareness existed in layers and that they were thoughts occurring below surface. The basic proposition of Freud was that our motivations remain mostly hidden in our unconscious minds. Moreover, they are actively withheld from consciousness by a repressive force. The executive apparatus of mind (the Ego) rejects any unconscious drives (the Id) that mind prompt behavior, which would be incompatible with our civilized conception of our self.

According to Mark Solms, Freud is back with his theory of unconscious. Further, Eric Kandel states that psycho-analysis is "still the most coherent and intellectually satisfying view of the mind. Freud introduces the central notion that most mental processes that determine our everyday thoughts, feelings and volitions occur unconsciously. Further, analysis of behavior of patients who are unable to consciously remember events that occurred after the damage of memory and coding structures show that their brains are clearly influenced by the forgotten events. There are different memory systems that process information consciously or unconsciously (implicitly and explicitly). Neuroscience have shown that the major brain structures essential for forming conscious (explicit) memories are not functional during the first two years of life, providing an elegant explanation of what Freud called infantile amnesia. As Freud surmised, it is not that we forget our earliest memories; we simply cannot recall them to consciousness.

B. Carl G. Jung and archetypes

Freud never abounded the basic Cartesian orientation of his theory. Gustav Jung, by contrast, was not so much interested in explaining psychological phenomena in terms of specific mechanisms, but rather attempted to understand the psyche in its totality and was particularly concerned with its relations to the wider environment. The key difference between the psychologies of Freud and Jung is their views of "*unconscious*". For Freud, the unconscious was predominantly personal in nature containing elements that had never been conscious and others that had been forgotten or repressed. Jung acknowledged those aspects, but he believed that unconscious was much more. Jung's concept of the collective unconscious distinguish his scope on psychology not only form Freud's but from all others. Jung saw the *unconscious* processes involving "collectively present dynamic patterns" which called *archetypes*. These patterns formed by the remote experience of the humanity, are reflected in dreams, as well as in the universal motives, found in mythos and fairy tales around the world. *Archetypes*, according to Jung, are "forms without content", representing merely the possibility of a certain type of perception and action. As we have described in chapter 15 our scope of the new Cartesian System or "*Nebulous Cartesian System*" fits better with more extended view of Carl G. Jung. Further, the modern view of *genetics* is better to reconcile with the explanations of the archetypes. After his longstanding interaction with the physicists due to Wolfgang Pauli, Jung was attracted from quantum mechanics. He described in "Aion" that we possibly have to move to transcendental theories as quantum theory in order to understand psychology of the brain. Our view on the related to quantum brain which is described in chapters 14, 15, and 16 is good agreement with the scope.

4. Herman Haken: Synergetics and LASER theory

A recent important development in the physics-like theories applied to biological systems is the framework synergetics. The word "synergetics" is composed of two Greek words and means "working together." Haken (1976) states: "In many disciplines, ranging from astrophysics over biology to sociology, we observe very often that cooperation of many individual parts of a system leads to macroscopic structures of functioning's." In its present state, synergetics focuses its attention on those situations, in which the functioning structures of the systems undergo changes on a macroscopic scale. In particular, synergetics investigates how the subsystems produce these changes in an entirely self-organized manner. The subsystems are usually discrete, *e.g.*, atoms, cells, or human beings. An important group of phenomena are oscillations (temporal structures) that occur in a self-organized manner. Here a rod of laser-active material with two mirrors at its end faces is pumped energetically from the outside, and the atoms emit light (Figure 1).

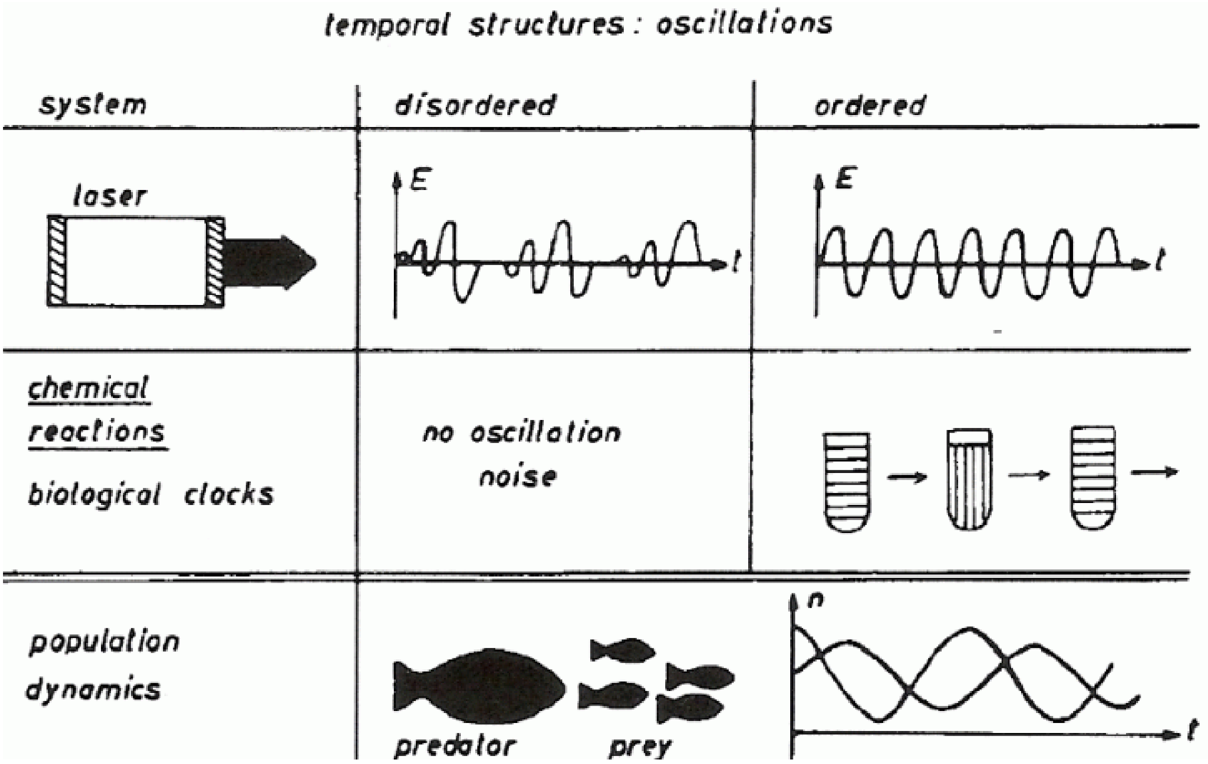

Figure 1. Self-organized oscillations from physics, chemistry, and population dynamics (From Haken, Synergetics, An Introduction. Springer, New York, 1977).

The essential feature to be understood is this: if the laser atoms are pumped only weakly by external sources, the laser acts as an ordinary lamp. The atoms, independently of each other, emit wave tracks with random phases. The coherence time of about 10^{-11}s is evident on a microscopic scale. The atoms, visualized as oscillating dipoles, are oscillating at random. If the pump is further increased, suddenly within a very sharp transition region the line width of laser light may become of the order of 1 cycle/s so that the laser is evidently in a new, highly ordered state on a macroscopic scale. The atomic dipoles now oscillate in phase, though they are excited by the pump completely at random. Thus, the atoms show the phenomenon of self-organization. Evidently the macroscopic properties of the laser have changed dramatically in a way reminiscent of the phase transition of, for example, the Ferro magnet. The laser analogy and the cooperative phenomena at the atomic level are presented here to provide an additional metaphor for the phenomenon of frequency stabilization, i.e., the transition to a highly ordered state on a macroscopic scale as seen in the brain responses."

5. The Importance of Einstein's Three Concepts in Brain Research: (1) Synchrony of Clocks, (2) Brownian motion, and (3) Unconscious Problem Solving

What is a clock? Any physical phenomenon may be used as a clock, provided it exactly repeats as many times as desired. Taking the interval between the beginning and the end of such an event as one unit of time, arbitrary time-intervals may be measured by the repetition of this physical process. All clocks, from the simple hourglass to the most refined instruments, are based on this idea. It is, therefore, inconvenient to have only one clock, therefore, if we know how to judge whether two, or more, clocks show the same time simultaneously and run in the same way; we can imagine as many clocks as we like in a given coordinating system (Einstein and Infeld, 1938). Provided the clocks are all at rest relative to the coordinating system, then they are "good" clocks and are *synchronized*, meaning that they show the same time simultaneously.

Synchronization of Clocks in the Brain (Synchronization of Oscillations of Neurons and of Neural Populations)

In the brain there are two classes of synchronized clocks. Firstly, synchronous neural oscillators in a given special brain structure (Singer, 1981; Eckhorn, 1988) and secondly, large scale synchrony between distant structures (Başar, 2004; Bressler, 2006; Varela *et al.*, 2002; von Stein and Sarnthein, 2000). The electroencephalogram (EEG) consists of the activity of an ensemble of generators producing oscillatory activity in several frequency ranges. These "*brain oscillators*" are active, usually, in a random way. However, with application of sensory-cognitive stimulation, these generators become coupled and synchronized; they start acting in a coherent way. This synchronization and enhancement of EEG activity produces the "evoked" or "event-related" oscillations that may be phase-locked to the stimulus. Or they may be non-phase-locked to the stimulus and thus have an "induced" character.

The compound event-related potential (ERP), which include the responses of ensembles of neural populations, represents a transition in the brain from a disordered state to an ordered one. The morphology of the ERP waveform is an outcome of the superposition of evoked/event-related oscillations. The "natural frequencies" of the brain which compose these oscillations range from the delta band (0.5-3.5 Hz) to theta (3.5-7 Hz), alpha (8-13 Hz) beta (15-30 Hz) and gamma band (30-70 Hz). That the oscillations are the basic responses of the brain nowadays finds strong support from a large number of neuroscientists who endeavor to understand the brain and the way it functions in cognition (Bressler, 2006; Freeman, 2006; Yordanova and Kolev, 1998).

In *Haken's Synergetics* (1977; 2004), the synchrony of oscillators plays a major role in the laser effect that are used in many applications. In biological systems and especially in the brain, on the other hand, the synchronization of clocks plays a crucial role in the realization and control of the integrative functions. While it is a technical phenomenon in physics, it is an explanatory model in biological systems. The electrocorticograms (EcoG) have a broad-band spectrum and within it, all frequencies are simultaneously present and are separately waxing, waning, and shifting phase (Bullock, 1988a and b; Bullock *et al.*, 1990).

There are also clocks that are not synchronized; according to Einstein there are *bad clocks*. Bad clocks are observed in case of pathologies as it will be presented in chapter 13.

Brownian motion

Einstein and Infeld (1938) described the tracks of the molecules as in the Brownian motion. However, they did not only describe the tracks, but also analyzed the causes of Brownian motion. In searching for causes of gravitation, Einstein wished to understand the causes of dissipating energy. To establish what is happening in the galactic system, he predicted the "black holes". Thus he arrived at not by only using the descriptions about the astrophysical events. He combined the existing knowledge on the motion of stars and also considered the laws of physics. With such an approach, he described the nature of stars and the galaxy; thereafter he arrived at the concept black holes, an existence invisible to conventional observation techniques.

What is Brownian motion? A suspended particle is constantly and randomly bombarded from all sides by the molecules in the liquid. If the particle is very small, the hits it takes from one side will be stronger than the bumps from the other side and this causes it to jump. These small random jumps make up the Brownian motion. The first mathematical theory of Brownian motion was developed by Einstein in 1905 (Einstein and Infeld, 1938). Einstein showed that the overall visible motion, averaged over many observations, exactly matches that expected if the little particles were atoms or molecules. The Brownian movement exists if the bombarded particles are sufficiently small. It exists because this bombardment, owing to its irregular and haphazard character, is not uniform from all sides and cannot be averaged out. The observed motion is, thus, the result of the unobservable one.

One of the aims of EEG research is try to discover brain functions. Accordingly the analysis of the trajectories in the “Brownian motion” initiated by Einstein (Einstein and Infeld, 1938) is an excellent theoretical model or metaphor for the brain functions, which is latently present in the puzzling engrams that the EEG-Oscillations form. In a number of explanatory formulations (Başar, Begleiter and Porjesz, Bressler and Tognoli, Bullock, Freeman, and Galambos), the trajectories of EEG-Oscillations are used for discovering their hidden sources (origins) These formulations show the immense usefulness of function-oriented investigation of brain signals for understanding the way the system functions. As Einstein’s fundamental model shows, signal analysis alone will never be sufficient.

Unconscious Problem Solving

In a describing the way Conan Doyle’s detective “Sherlock Holmes”, solves problems, Einstein points out the following:

> “The great detective, however, realizes that no further investigation is needed at the moment, and that only pure thinking will show the pattern of relation between the collected facts. So he plays his violin, or lounges in his armchair enjoying a pipe, when suddenly, by Jove, he has it! Not only does he have an explanation for the clues at hand, but he knows that certain other events must have happened. Since he now knows exactly where to look for it, he may go out, if he likes, to collect further confirmation on his theory.”

This very important viewpoint is presented in chapter 20 on unconscious states. Although in the present chapter only the empirically founded facts are analyzed, it is important to emphasize here, that Einstein too was interested in metaphysics of the brain.

6. Werner Heisenberg

Microscope Model of Werner Heisenberg

The uncertainty principle in Quantum Physics was formulated by Werner Heisenberg during the period of Copenhagen School at the beginning of twentieth century. In order to justify the philosophical framework of this principle, Heisenberg developed a model of thought[4]. If one day a microscope with very high resolution could be used, the experimenter would be able to observe the interaction of a gamma ray with an electron in the aperture of the microscope. Heisenberg assumes that at the time the gamma ray, which is used for the illumination of the electrode, would undergo an interaction with the electron. Meaning that supplying energy to the electron should change the position of the electron according to the laws of physical motion. When the observer aims to localize the position of the electrode, they will certainly fail. He would then observe not the exact position of the electron at the moment of collision with the *x*-ray light but would see only the position of the electron following the displacement. Without using a gamma light no observation is possible, by using the light the exact localization of the electron is impossible. This model of thought was subject of discussions after the development of quantum mechanics. Finally, the experimental requirements of Heisenberg were fulfilled and the microscope theory was supported by experiments of Christopher Foot (1994) and in this way Heisenberg’s dream was realized.

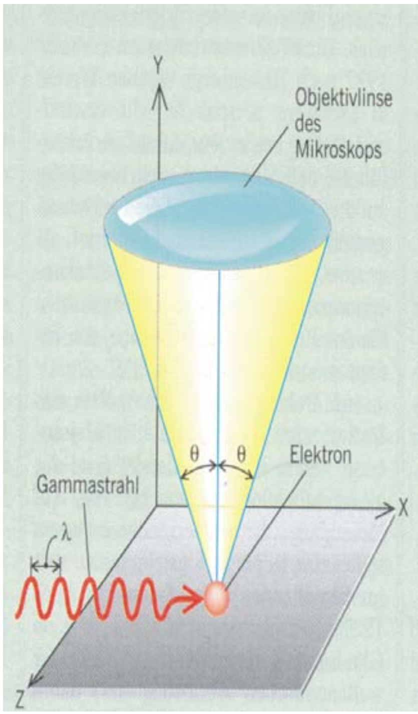

Figure 2. The Gedanken- Experiment by Werner Heisenberg: “Microscope Theory”

[4] Works of N. Bohr, E. Schrödinger, W. Pauli, Dirac, M. Born, C. F. Weizsäcker

Is it possible to translate the uncertainty principle manifested by the microscope thought experiment to brain research? Considering, now, the experimental recording in Figure 3 below, when the brain is stimulated by a sequence of peripheral stimulations the spontaneous activity of the brain does incessantly change. The development of alpha activity with increasing amplitudes has, in turn, an important influence on the alpha responses. The brain is learning and goes from a preliminary state to a learnt state. The same situation occurs with the microscope analogy; at the moment of application of the cognitive input the state of the brain is changed accordingly it is not possible to determine the exact cognitive response to cognitive inputs or to cognitive inputs with emotional components.

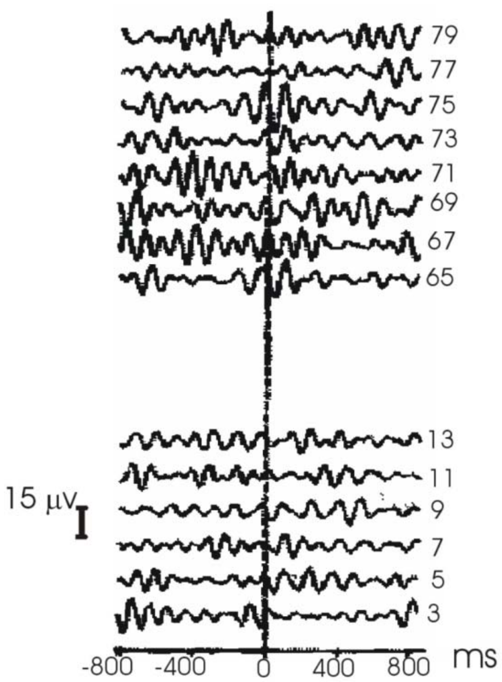

Figure 3. Development of alpha activity upon sensory stimulation.

The laws of quantum physics are of a statistical character. This means that they are valid for not a single system but for an aggregation of identical system; they cannot be confirmed by measurements on one individual but by a series of repeated measurements from that individual. In Einstein's words *"Quantum physics formulates laws governing crowds and not individuals. Not properties but probabilities are described."(Reference)* Laws do not disclose the future of systems but govern the temporal changes in these probabilities. In quantum physics, laws are valid for a great congregation of individuals. Similarly, laws concerning the brain specifically in cognitive processing are valid not for single neurons but for neural populations. What applies to quantum mechanics also applies to the dynamics of chaotic systems. In such systems, also, not properties but probabilities are described, laws disclose the change of the probabilities over time, and they are valid for congregations of individuals

7. Boltzmann's Statistical Mechanics Statistical Mechanics in Biology and Physics from Griffith's Perspective (1971)

Griffith (1971) discussed concepts of *statistical neuron-dynamics* and tried to formulate the similarity between *statistical mechanics* and *neurodynamics* as follows:

> "The situation is superficially very similar to that which is obtained in statistical mechanics, as it applies to the relation between macroscopic thermodynamic quantities and the underlying microscopic description in terms of the complete specification of the states of all the individual atoms or molecules,... These are, firstly, that we could not, even if we knew all the necessary parameters, actually solve in detail the 10^{10} or more coupled neuronal "equations of motion" necessary to follow the state of the system in detail as a function of time. Secondly, that there exists a simpler "macroscopic" level of description which is really our main ultimate object of interest so that we do not wish, even if we could, to follow the "microscopic" state in detail but merely wish to use it to understand the time development of the macroscopic state. One most important aspect of this is that we only wish to specify, at the macroscopic level, the initial conditions of any calculation we may make. This leads immediately to the problem of whether the fundamental assumptions of equal a priori probabilities and random a priori phases hold for nerve cell aggregates, and, if not, whether we can find anything to replace them."

Griffith's remarks are nowadays more important than 30 years ago since new trends or new avenues in brain research clearly indicated the need to introduce new frameworks to analyze the integrative brain function by introducing *cell aggregates instead of single cells.*

Global Neurodynamics: The view of Rosen (1969)

A similar problem statement was created by Rosen (1969) asking the following question: "What *is the role of statistical mechanics in gas dynamics?*" The gas laws that describe the gas dynamics are based on the ensemble of molecules in an isolated system. One does not describe gas dynamics with the dynamics of single molecules in an isolated system. However, after the laws are experimentally determined, one tries to correlate the macro-system laws with dynamics in the micro-level, i.e., with gas molecules. In other words, the laws of gas dynamics were determined before these laws were exactly correlated with molecular properties. This is a complementary explanation to Griffith's problem described above.

Başar (1980; 1998) commented on the questions of Rosen and Griffith as follows: In the analysis of brain waves we are certainly interested to discover the particular properties of individual neurons and their relation to the gross activity. To further examine the problem of the correlation between single unit activity (*micro-activity)* and gross activity (*macro-activity*) Rosen (1969) explained the concepts of statistical mechanics and physics and their relation to Neurobiology as follows: What is the micro-description?

> "We know, that here, the fundamental state variables are the displacements and momenta of the individual particles which make up our system. According to Newtonian dynamics, the kinetic properties of the system are given by the equations of motion of the system, which express the momenta as functions of the state variables.
>
> The basic postulates of "Newtonian Dynamics" are the following point: Knowing the state variables at one instant and the equations of motion, we are supposed to be able to answer any meaningful question that can be asked about the system at any level. Statistical mechanics however, identifies a macro-state with a class of underlying microstates, and then expresses the global state variables as averages of appropriately chosen micro-observables over the corresponding class of microstates."

8. Santiago Ramon y Cajal

In the twentieth century a great number of research results suggest that it is possible to understand the functioning of the brain once there is sufficient explanation for the specific functions of individual nerve cells and their connections. The transformation of neural information and its storage as memory involve only nerve cells and their interconnections.

However, at the end of the nineteenth century it was generally believed that the brain is made up of a continuous net of nerve tissue, *'reticular network'* or *'syncytium'*. The first morphological studies of the nervous system were done by the Spanish anatomist Santiago Ramon y Cajal. He proposed that the functions of the brain could be understood by analyzing the functional architecture of the nervous system. Applying Golgi's silver staining technique to the study of nerve tissue, he observed that only some cells are stained in their entirety. This led to his formulation of the 'neuron doctrine' which states that the brain is made up of discrete units rather than a continuous net of nerve tissue or 'syncytium' as was originally thought. He proposed that nerve impulses travel from the dendrites of a neuron to its cell body and then along the axon to the dendrites of the neighboring neuron. This flow of information would be a finite process.

The neuron is a transmitter, because it converts the conducted electrical signals into chemical messages and then conveys or 'transmits' them from one neuron to a neighboring neuron. Neurons are connected at specialized contact points the 'synapses'. English physiologist Charles Sherrington (1861-1952) worked out the details of the reflex arc in the spinal cord of mammals (The Integrative Action of the Nervous System, published in 1906). Although the book of Sherrington was republished in 1948 it is to note that he did not include memory and cognitive functions in the integrated action of the nervous system.

9. Hans Berger and Electroencephalography (EEG)

At the turn of the 20th century, the morphological studies carried out by Ramon y Cajal (1911) and Charles Sherrington's physiological approach opened the way to the "single-neuron doctrine" by introducing the notion of *"one ultimate pontifical nerve-cell"* which integrates the CNS function. In this concept integration was related to motor activity; the functional mapping was a type of movement mapping. Although this approach dominated 20th century-neuroscience it had a major shortcoming in that cognitive functions and memory were not integrated into the neuron doctrine or in its derivatives, even, the cerebellum was not included in Sherrington's model. The description of integration needs morphological descriptions, measurements in the time space and the analysis of coherence functions. Therefore, to new concept emerging from the study of brain oscillations, the role of time space and coherence also gained considerable importance.

The discovery of the EEG was followed by an explosion of publications related to brain function. The hope was renewed that a physical correlate of mental performances of the brain could now be tapped, a "psychic energy" in Hans Berger's words (1929). However, from 1960's the trend induced by Hans Berger and experimentally supported by Edgar Adrian remained in the shadow of neurophysiology research by using the single neuron approach and the methodology initiated by Adrian.

10. Hebb, Hayek and Helmholtz

In the first half of the twentieth century two important books introduced outstanding holistic and dynamic approaches to brain functioning, Donald Hebb's book (1949) related to the organization of behavior inspired several neuroscientists in search of the "Hebb neuron". Speculations on the existence of the Hebb neuron and Hebb's theory is explained in Chapters 7 and 8. According to Hebb, the functioning of the brain after learning is a different brain compared with the same brain before the learning process.

Although Friedrich Hayek (1952) developed his theory of "*theoretical psychology*" almost twenty years prior to the publication of Hebb's book, Hayek's book was published much later (1952). The chain of the ideas developed in this theory is highly pertinent to the dynamic nature of the living brain. Hayek states:

> " We shall see that the mental and the physical word are in the sense two different orders in which the same element can be arranged; though ultimately we shall recognize the mental order as part of the physical order."

Hayek argues that it is the whole history of the organism, which it will determine its action, new factors will contribute to this determination on later occasions which were not present on the first. This idea is much better explained in the following sentence: "We shall find out that the same set of external stimuli will not always produce the same responses, but also that altogether new responses will occur." Here is a dynamic interpretation of brain responsiveness similar to the statement made by the Ionian philosopher Heraclites: *"One never can step twice into the same river."* One of Hayek's most important statements is related to perception and memory in that they are inseparable functions. This view later received excellent support from Fuster, Baddeley, Desimone and Başar. Perception is, therefore, always an interpretation, the placing of something into one of several classes of objects. An event of an entirely new kind, which has never occurred before, and sets up impulses which arrive in the brain for the first time could not be perceived at all.

Here it is important to emphasize the parallels with the theories of Hebb and Hayek. The brain, which is learning and or the brain which is targeted by several stimuli will be changed physiologically and anatomically. According to Hebb, there are changes in the connectivity of neurons in the learning brain, thus changing both, the anatomical structure and electrical activity. Hebb and Hayek both discussed the dynamic brain.

Although both these scientists did not mention structural changes and entropy changes during learning it is clear that the concept of altered entropy is in the context of the theories of both scientists. This central question will be returned to in Chapter 7. Although theoreticians as Prigogine and Wiener took advantage of Hayek and Hebb's biological models of they did not find an important bridge between neural connectivity, and changes in the entropy in the learning brain. In Chapter 9 an attempt will be made to create this bridge.

Hayek asks the question "what is mind?" and he discusses the relation between mind and body or between mental and physical events. The difficulty of any fruitful discussion of the body-mind problem consists largely in differentiating what part of our knowledge can properly be described as knowledge of mental events as distinguished from our knowledge of physical events. After discussing physical events, the physiological responses to physical events, Hayek comes to the following definition: What we call "mind" is a particular order of a set of events taking place in some organism and in some manner related but not identical to the physical order of events in the environment.

Hayek considers the nervous system as an instrument of classification. He classifies *"emotion"* as a special type of disposition for a type of action, which in the first instance are not necessitated by a primary change in the state of the organism, but which are complexes of responses appropriate to a variety of environmental conditions. *"Fear" and "anger" "sorrow" and "joy"*, are attitudes toward the environment, and particularly towards fellow members of the same species. This means that a great variety of external events, and also some condition of the organism itself, may evoke one of several patterns of attitudes or dispositions which will affect the perception of, and the responses to, any external event. "Emotions" may thus be described as "affective qualities similar to the sensory qualities and forming part of the same comprehensive order of mental qualities."

According to Hayek, the term experience is related to memory however, it is a type of plastic memory if stimuli are applied to the CNS this system gains type of experience. However, when the same stimuli occur again they have special significance for the organism at the time not having any meaning for the individual. Hayek proposes that we must distinguish between two different kinds of physiological "memory" or traces left behind by the action of any stimulus: One is the semi-permanent change in the structure of connections or paths and which determines the courses through which any change of impulses can run (similar to Hebb's principle). The other is the pattern of active impulses proceeding at any moment as results of a stimuli received in the present past, and perceived also as merely part of continuous flow of impulses of central origin, which never altogether ceases even no external stimuli are received. At this point the reader can refer to chapters 7 and 8 which are related to memory.

Hayek's most important conclusion on the evaluation of impulses from the organism is that it is the whole story of the organism which will determine its action, new factors will contribute to this determination on the later occasion which were not present on the first *"we shall find not only the same set of external stimuli will not always produce the same responses, but also that altogether new responses will occur."* This is similar to the coordinated movement of the organism which is not determined by the movement of an individual muscle but the whole complex of body muscles.

Başar (1983; 1998) introduced the "Brain S-matrix", which takes into account the whole history of organism. Hayek does not comment on the S-matrix, but this concept includes the principle of application of the S-matrix which includes the history of whole brain-body organism.

Hayek explains perception as an interpretation or the placing of something into one or several classes of objects. An entirely new kind of event, which has never occurred before, and which sets up impulses that arrive in the brain for the first time could not be perceived at all. This explanation is in accordance with Helmholtz's opinion in regard to perception.

Helmholtz puts the emphasis on the effect of experience in determining sensory qualities and he goes far beyond ascribing to experience the creation of their spatial order. It is today widely recognized that "the manner in which we see things of the external world is sometimes affected by experience to an overwhelming extent" and that "it is often difficult to decide, which of our visual experiences are determined immediately by sensation and which, on the contrary, are determined by experience and practice. His conception of the "*unconscious inference*" by which stimuli that do not lead to conscious experience and yet utilized in the perception of a complex position, comes very close to the theory developed here.

Hayek's conclusion is that the mind must remain forever in a realm of its own which we can now only directly experience it, but which we shall never be able fully to explain or to "reduce" to something else. Even though we may indicate that the mental event of the kind that we experience can be produced by the same forces which operate in the rest of nature. We shall never be able to say, which particular physical events "correspond" to a particular mental event.

11. Jacques Monod: The Chance and the Necessity (1964)

Monod actually begins by showing that the difference between natural and artificial things is illusory, as natural things are also built for a purpose. Living beings are characterized by three properties: teleonomy (organisms are endowed with a purpose which is inherent in their structure and determines their behavior); autonomous morphogenesis (the structure of a living organism is due to interactions within the organism itself); and reproductive invariance (the source of information expressed in a living organism is another structurally identical object - it is the information corresponding to their own structure).

From his analysis of how DNA and proteins work, Monod concludes that humans are the product of *chance*, *an accident in the universe*. The paradox of DNA is that a mono-dimensional structure like the *genome* could specify the function of a three-dimensional structure like the body: the function of a protein is underspecified in the code, it is the environment that determines a unique interpretation. There is no causal connection between the syntactic (genetic) information and the semantic (phenotypic) information that results from it. Then the growth of our body, the spontaneous and autonomous morphogenesis, rests upon the properties of proteins. Monod concludes that life was born by accident; then evolved by natural selection as discovered by Darwin. Biological information is inherently determined by chance. The concept developed by Monod is discussed in details in Chapter 19 "*Creative Evolution*".

12. Otto Loewi and Discovery of Acetylcholine

One of the most important developments at the beginning of 20th century is the experiment of Loewi leading to discovery of Acetylcholine. The role of transmitters in the understanding of mind is crucial, and what Loewi has achieved belong to the most important discoveries in brain research (Figure 4).

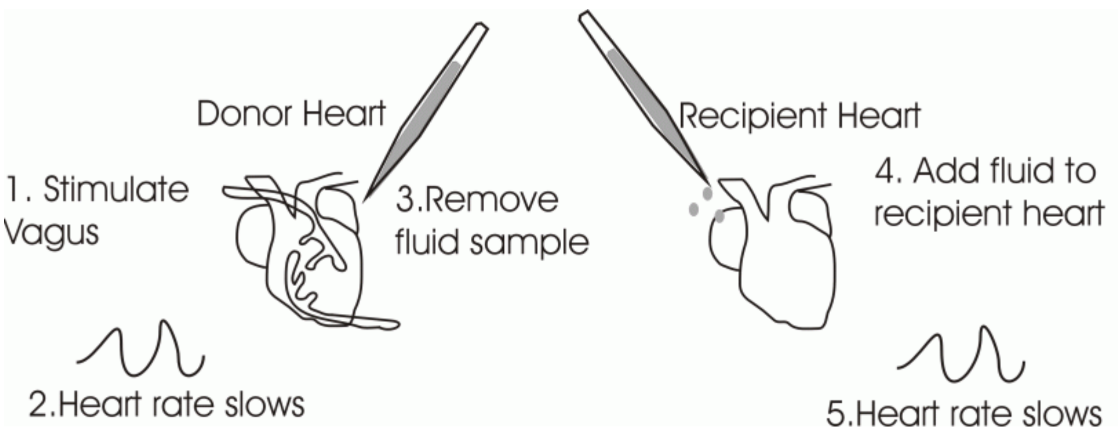

Figure 4. Experiment of Otto Loewi

In his most famous experiment, Otto Loewi took fluid from one frog heart and applied it to another, slowing the second heart and showing that synaptic signaling used chemical messengers. He called the chemical Vagusstoff. It was later found that this chemical corresponded to acetylcholine.

13 . Why the Concept "Quantum Brain" was not discovered in 1940s

The presented survey shows that fundamental results were already present for developing approaches related to "Quantum Brain" already in 1940s, except the theory of H. Haken. Heisenberg's Uncertainly Principle, Hayek's and Hebb's theories related to Dynamic Memory, Bergson's view comparing the physical time and the intuition, Boltzmann statistics viewed by Rosen and Griffith and Einstein's idea of "Quantum Theory" and "Synchronization of Clocks", and Hans Berger's' oscillations could not be jointly discussed in 1940's or at the beginning of 1950's.

If a Solvay Conference similar to that one in Physics in 1927 could be organized in 1940s and named "*Neuro-Solvay Conference*", furthered chaired by Norbert Wiener with invited speakers described in this article it would be most possible to start the concept of "Quantum Brain" 60-70 years ago.

Principles and findings were already existent, only the idea to bring appropriate scientists together was missing.

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