OPINION AND PERSPECTIVES

An Essay on Darwin's Theory and Bergson's Creative Evolution in the Era of NeuroQuantology

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Abstract

Charles Darwins's evolution theory was surveyed and analyzed by Henri Bergson in his book "Evolution Creatrice" (1907). Bergson described the importance of "intuition" and "cognitive processes" during evolution. The present essay describes the importance of entropy changes during evolution of species and development of cognition and intuition. The importance of Bergson's philosophy in modern sciences is globally explained.

Key Words: Darwin, Bergson, evolution, neuroquantology, intuition, entropy

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1 Darwinism and Evolution Créatrice

1.1 Darwin's Theory

One of the most revolutionary developments in biological sciences was Charles Darwin's publication "*On the Origin of Species*" (1859). Darwin worked within a framework of the living world as initiated earlier by Jean-Baptiste de Lamarck (1809). Lamarck indicated two main themes in his work. (1) The first was that the environment gives rise to changes in animals. He described examples of the presence of teeth in mammals and the absence of teeth in birds as an evidence of this principle. (2) The second principle was that life was structured in an orderly manner and that many different parts of all bodies make it possible for the organic movements of animals (Lamarck (1809).

Darwin's theory rests on two fundamental ideas: The first is the concept of "*heritable variation*". This is appearing spontaneously and at random as it was individual members of a population and is immediately transmitted through descends. The second is the idea of "*natural selection*", which results from a "*struggle for life*". Only individuals whose hereditary endowments able them to survive in a particular environment can multiply and perpetuate the species.

A review of Darwin's "Origin of Species" shows that the word "*Brain*" can be found only in one short paragraph. The reason is clear: Around the 1850's knowledge of the anatomy and physiology of the brain was very rudimentary. It should also be noted that Darwin did not mention anything about cognition, or about network abilities of the brain. This is deceptive because, in his notes, Darwin frequently refers to the brain as the organ of thought and behavior, and to heredity of behavior as being dependent on the heredity of brain structure (de Beer, 1960). As Smuldres indicates, in later editions of the "Origin of Species", additional mentions of the brain do

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arise. The sixth edition contains a passage which explicitly states that natural selection applies to the brain as it does to all the other organs (Darwin, 1872: p. 98; Smulders, 2009).

50 years after its publication, Henri Bergson closely analyzed Darwin's theory in his work "Creative Evolution". An idea with the goal of explaining evolution, the "Élan vital" first appeared in "Creative Evolution" (1907). Bergson portrays "Élan vital" is a kind of vital impetus, which explains evolution in a less mechanical and livelier manner, as well as accounting for the creative impulse of mankind. Darwin's evolution theory provided an excellent model for Bergson's description of "intuitive processes and creativity". He formulated a theory of "*intuition*", stating that this ability is unique among humans. Like other researchers of the time, Bergson was limited by the rudimentary level of contemporary neurophysiologic and anatomical knowledge. In comparison to Bergson's time, present-day knowledge of neural networks, electrophysiology of neural populations, histology and neural transmitters is much more advanced.

Contemporary knowledge enables us to say more: We reviewed the work of Hebb (1949), Hayek (1952), and Edelman (1978) on learning of neural networks, in which connectivity of neural networks or neurons achieve changes in morphological structures and connective abilities of the brain in a very short time (sections 5.1, 5.2, 5.3). The theory proposed by Hebb is supported experimentally by the work of Kandel and Schwartz (1982) on the *Aplysia* model.

Despite the richness of empirical data available in the fields of anatomy, neurophysiology and psychology, research on fundamental correlates of "*mind*" is detached from philosophy and philosophical frameworks. Accordingly, simple measurement strategies overwhelmed fundamental conceptual questions. We therefore tentatively attempt to reconcile the relevant natural philosophy of Bergson with contemporary knowledge, in the hope of adding value to the progress of neuroscience.

Henri Bergson (1907), who studied the work of Charles Darwin, came to the conclusion that the *superiority of the human brain* in comparison to lower species is defined by the ability of "*intuitive and creative thinking*".

Bergson (1907) emphasized three types of mental abilities during evolution of species: *instinct, intelligence and intuition*. Instincts are observed in lower species such as invertebrates; intelligent behavior belongs also to functional properties of lower vertebrates and mammals. Writing at the beginning of the twentieth century, Bergson did not have the opportunity to observe electrophysiological correlates of evolution. He was not in the knowledge of the theory of Hebb (1949).

Knowledge of the morphology of the evolving brain and the morphology of maturation of the human brain were not yet established and/ or discovered. Subsequent knowledge and new tools developed during the 20th and 21st centuries provide an opportunity to analytically discuss the Bergson's theory of intuition. The ability to interpret transitions in the evolution of brain waves presents a new, highly efficient framework to interpret higher brain activity.

Further, according to Bergson, in higher vertebrates, a radical distinction exists between pure automatism, (originating mainly in the spinal cord), and voluntary activity, which requires the intervention of the brain. Bergson (1907) stated that there are three types of judgments or development of skills. All lower vertebrates have instincts, which are regular and very simple, and also more complicated stereotypical behavioral patterns. A number of more developed animals more closely resemble humans, in that they display intelligence and not only automatism. In humans, parallel to almost automatic spinal cords reflexes, one also observes intelligent behavior, coordinated by the cerebral cortex. Humans also display a third mechanism, which is described as "*intuition*[2]". Bergson assumed that the most important characteristic of humans is the ability to make use of this third type of cognition called "intuition". This is also, according to Descartes (1840) and Locke (1690), what differentiates humans from other species.

[2] Definition of Intuition: Intuition is the act or faculty of knowing immediately, directly and holistically without rational processes, and without being aware of how we know. It is also the channel or process through which we access realms of truth and knowledge.

In order to open a new gateway to analyze the electrical signals during human evolution, we confine our attention to three types of tracks: The first is the change of electrical *oscillations* through the evolution of species; the second is the measurement of *coherence* within the brain during its evolution; the third track is the analysis of *entropy*. The third track will be supported and extended through the work of Hebb, Kandel and Edelman that are, related to re-organization processes in neural populations.

The substance of the present essay is based partly on a long-term collaboration with Theodore Bullock between 1984 and 2005, conducted in San Diego and Lübeck.

2 Electrical Activity from *Aplysia* Ganglion to Human Frontal Cortex. Possible Role of the "Alpha Oscillation" During Evolution of Species, in "Creative Evolution" and Maturating Brain

Alpha activity is possibly the most important dynamic pattern in Brain-Body Interaction (Gebber et al., 1995, 1999; Başar and Güntekin, 2007). In the isolated ganglia of invertebrates' scarcely very little spontaneous oscillation in the same frequency ranges of EEG oscillations and also evoked oscillations were recorded. Goldfish, Ray or *Aplysia* cannot develop spontaneous regular and large and rhythmic 10 Hz alpha activity. Animal recordings clearly indicate that entropy is high. In contrast, the alpha activity in human subjects depicts a high level of regularity, which is possibly due to synchronization between neurons. Accordingly, the entropy of alpha is much lower in human EEG recordings. Although the frequencies of EEG oscillations seem to be somewhat invariant during evolution, in human electrical signals the degree of synchrony is much higher and the entropy is lower (Rosso et al., 2001).

Başar et al. (1999), Schütt et al. (1999) and Başar and Güntekin (2009) described the changing oscillations, particularly of the alpha activity, in the evolution of the brains: The alpha activity was very weak in recording spontaneous and evoked activities of invertebrate ganglia (*Aplysia* and *Helix pomatia*). In Table 1, it can clearly be seen that there are almost no alpha responses in these species. The more highly evolved fish brain displays more efficient alpha responsiveness; in the cat brain, dominant and powerful alpha responses are seen, although spontaneous alpha is scarcely recorded; finally, in the human cortical recordings, there is huge alpha activity, reaching amplitudes up to hundred µV. However, the human alpha activity is observed only in young and middle aged human subjects; babies do not show alpha activity until the age of three years. Spectral analyses of spontaneous and evoked activities depict clear differences in the alpha activity in the maturating brain (See Başar et al., 1999; Başar, 1998). Thus, alpha patterns are strongly dynamic manifestations of the evolving and maturating brain.

What may be the role of alpha activity during the evolution of species? According to the concept proposed by Bergson (1907), lower animals and plants do not have the ability to perform developed cognitive tasks. Invertebrates function instinctively, as we also described as the result of phyletic memory and stereotypical behaviour patterns. At a higher stage of evolution, animals start to display intelligent behaviour and are able to perform some forms of cognitive tasks. This ability was described by Blaise Pascal as the "*geometrical mind"*. Developed mammalian species such as cats certainly display this kind of performance, and are more intelligent then lower vertebrates; they are able to develop new abilities of hunting and searching. Cat brains show a higher degree of spontaneous and evoked alpha In addition, the cat brain can selectively respond to sensory stimulation and also develop responses based upon cognitive loading (Başar-Eroğlu and Başar, 1991; Başar-Eroğlu et al., 1992). However, the cat brain lacks the abundant and high amplitude synchronized spontaneous 10 Hz activity seen in human alpha activity (Başar, 1980). Humans have the ability of speech, they can solve geometric problems, and they can invent new machines and can investigate and substantiate theoretical problems, such search the cause of gravitation and the motion of our planetary system. This present several research questions: Is the presence of alpha activity a consequence of the highly sophisticated human brain in comparison to the cat? Or do the creative evolution and the creativity of the human brain trigger this alpha activity? We will discuss the potential existence of a Maxwell Demon in section 4.

2.1 The Evolving of Alpha Activity during Cognitive Loading and the Role of Alpha Activity in the Maturating Brain.

High amplitude and recurrent alpha activities are usually recorded at the end of an experimental session in which subjects are induced to develop cognitive tasks or pure thinking (Başar et al., 1989). Also, in an experimental paradigm with cognitive tasks, the event related oscillations in the alpha frequency range are more prolonged. Here again, the mechanisms providing high level of cognition are accompanied by increased amplitude of 10 Hz oscillations.

The increase in the amplitude of 10 Hz oscillation is accompanied, in most cases, by recurrent alpha wave packets and also regularity of the alpha oscillation shapes. The studied brain structures move from a state of disordered activity to a state of ordered activity, indicating a decrease in entropy. We can summarize this point by simply saying that the cognitive excitation of the mature brain elicits higher synchronization and a state of lower entropy. This process will be explained in further detail in Figure 2.

Children do not show alpha activity until the age of three years. The cognitive performance of children is also not developing until the age of three years. Young adults have better cognitive performance and speech ability; their alpha activity is also highly increased. In other words, during the maturation of the human brain, the alpha activity also reaches a type of micro-evolution. As the alpha activity reaches higher amplitudes and an almost sinusoidal waveform, its entropy is decreasing. This means that the maturating brain's alpha activity is involved with the transition from a high entropy state to a low entropy state. We can easily assume that the higher cognitive ability of the adult brain in comparison to the child brain is accompanied by the entropy decrease of alpha activity.

3 The Role of "Coherence" in the Evolution of Brains

The term "coherence" refers to a pair-wise measure of correlation at each frequency between two simultaneous time series. This is the best estimator for synchrony, to date. It tells us that the eye is a poor estimator - confusing amplitude with synchrony. According to Bullock et al. (1995), there seems to be a difference between biological classes, with virtually no synchrony at any frequency in sea slugs (*Aplysia*), even at less than 1 millimeter and even for low frequencies. Bullock and Başar (1988) previously showed that fish had significant coherence at one or two millimeters; turtles and geckos displayed slightly more and mammals still more. Bullock et al. (1990) found that detecting EEGs from the brain surface on the smooth brain –of a rabbit, the average of many pairs showed coherence of approximately 50% when the electrodes were about 3 to 5 mm apart, falling to chance level at approximately 7 to 10 mm spacing (Bullock and McClune, 1989; Bullock, 2002; Bullock et al., 1990, 1995).

Table 1. Comparative presentation of maxima in frequency characteristics in different species (Modified from Başar et al., 1999; Başar and Güntekin, 2009).

Frequency band (Hz) Species	**1-8**	**8-15**	**15-30**	**30-48**	**52-100**
	Maxima in frequency characteristics (Hz)				
Helix					
Pleural r.	5	-	20	-	-
Parietal r.	2	-	16	40	65
Visceral r.	2	-	15	35	60
Parietal l.	2		to	50	-
Pleural l.	2	9	18	40	75
Aplysia					
Group I	2	to	20	40	100
Group II	3		25	-	60
Ray					
Mesencephalon	5	-	28	-	-
Medulla	-	9	16;24	40	-
Goldfish					
Telencephalon	3	10	-	35	90;100
Mesencephalon	-	-	-	30	80;100
Medulla	-	-	-	-	80;90
Cat					
GEA	5	-	18	40	80
RF	5	11	25	40	85
HI	5	12	-	45	-
Human					
Cz	4	8	25	40	-
O	3,5	10	25	45	75
P	6	10	20	40	70
F	4	8	20	35;45	-

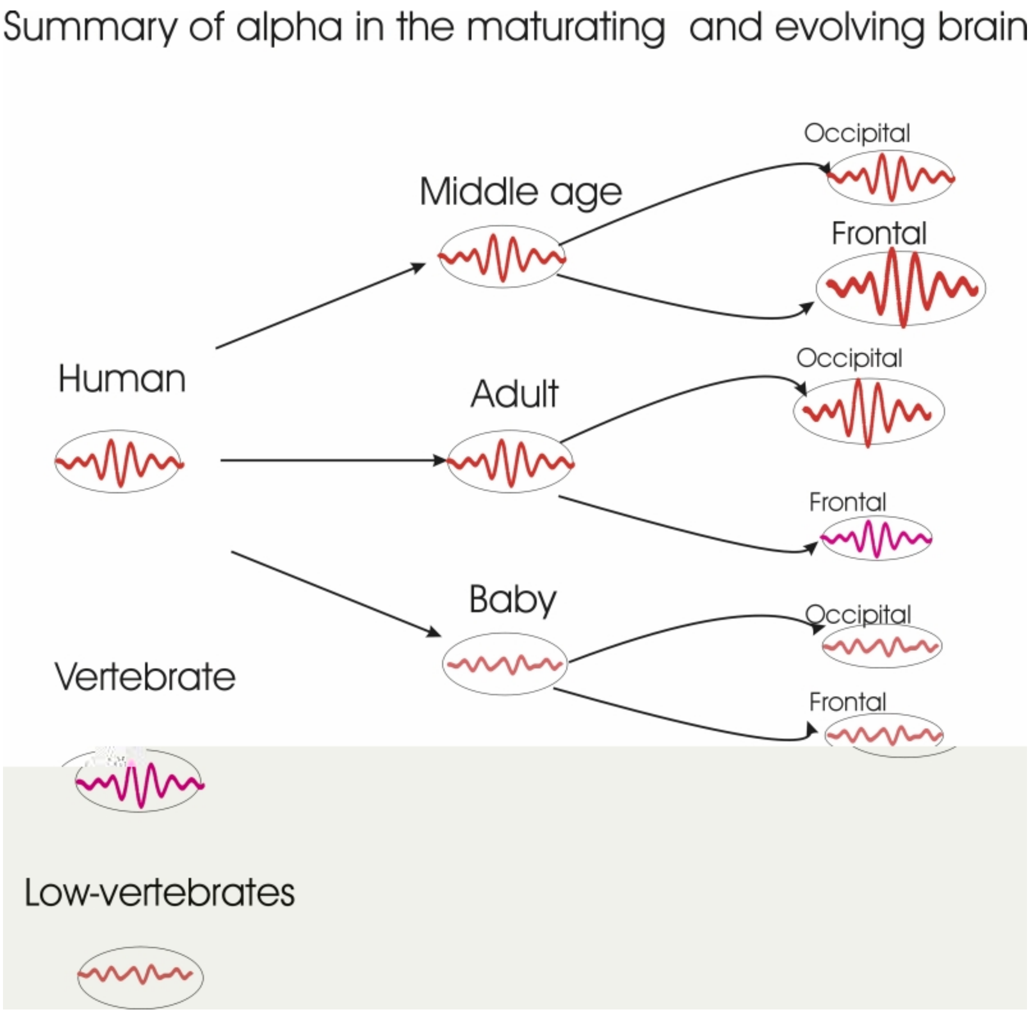

Figure 2. Globally illustrated waveforms of alpha activity during evolution of species and during maturation of the human brain (Modified from Başar and Güntekin, 2009).

Human subdural recordings are approximately double those numbers, but the electrodes are quite different, so a meaningful comparison is not possible. Bullock emphasized that the distance for 0.5 coherence varies greatly from pair to pair, place to place and moment to moment. The average is much greater in scalp recordings and smaller with intracortical micro-needle recordings. All these features underline the main finding microstructure and widely varying dynamics in time and space.

4 Maxwell's Demon in Entropy of Cognitive Processes

4.1 What is Maxwell's Demon

Maxwell's Demon is an imaginary creature that the mathematician James Clerk Maxwell proposed to contradict the second law of thermodynamics (1871). Suppose that a box is filled with a gas at some temperature; accordingly, the average speed of the molecules within the box depends on the temperature. Some of the molecules will be moving faster than average (higher energy) and some will be moving slower than average (lower energy). Further, suppose that a wall is placed across the middle of the box, separating it into left and right sides. Both sides of the box are initially filled with the gas at the same temperature. Maxwell imagined a molecule sized trap door in the partition, operated by the demon, which is observing the molecules. When a molecule moving faster than average approaches the door, the demon allows it to pas to the left side (by opening the door if the molecule comes from the right); when a slower than average molecule approaches the door, the demon ensures that it ends up on the right side. The result of these operations is a box in which all the faster than average (higher temperature) gas molecules are in the left side and all the slower than average (lower temperature) molecules are in the right side.

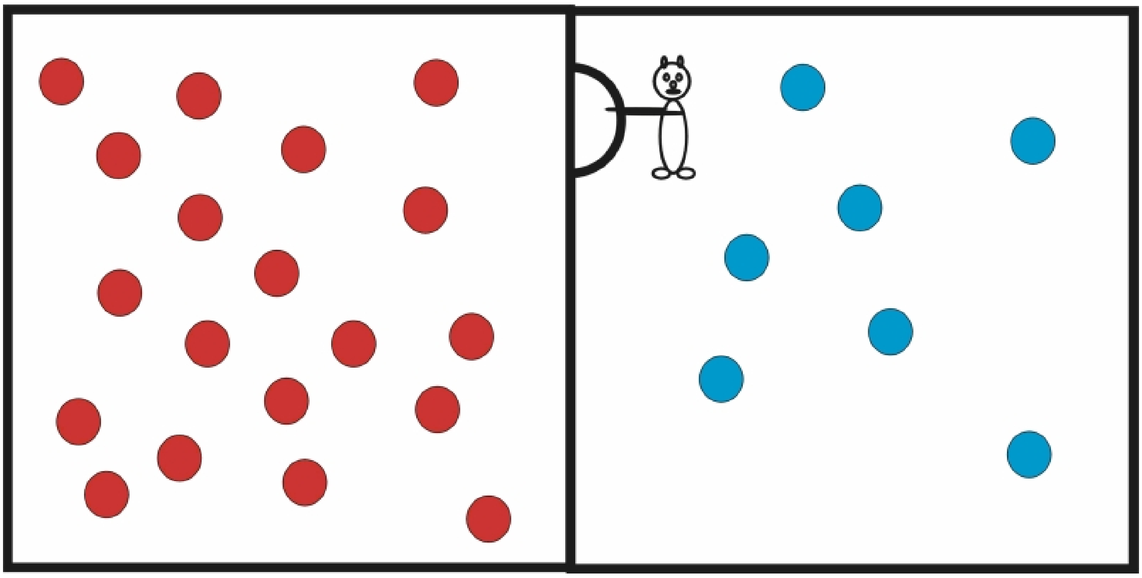

Figure 3. Schematic Figure of "Maxwell's Demon"

According to several authors, (References see also Szilard, 1929; Prigogine, 1980; Monod, 1970) this theoretical situation appeared to contradict the second law of thermodynamics. In order to explain this paradox, it was pointed out that, to realize such an outcome, the demon would still need to use energy to observe the energy level of the molecules (in the form of photons for example). The demon itself (plus the trap door mechanism) would gain entropy from the gas as it moved the trap door. Thus, the total entropy of the system still increases.

In Maxwell's "thought experiment", the demon manages to *decrease* the entropy, in other words it *increases* the amount of energy available by *increasing* its knowledge about the motion of all the molecules. Norbert Wiener (1948) refers to this as "the Maxwell demon"; the phrase "Maxwell's demon" is also used.

Wiener (1948) further asks the question: "Why wouldn't a setup like Maxwell's demon work?" Any real "demon" would not be a disembodied spirit, receiving its information telepathically. To acquire information about the world it is necessary to be in physical interaction with it and, on the atomic and molecular scale, it is not possible to ignore the *quantum mechanical nature of the world*. For instance, to be able to observe the molecules, the "demon" would need to absorb whole photons at a time, and any detailed version of the thought experiment will encounter the uncertainty principle, and the fact that an interacting "demon" will acquire the same temperature as the rest of the system.

The link between thermodynamics and quantum physics is even stronger: macroscopic entropy can only be computed correctly from cumulative contributions from microscopic states.

4.2 Does a Maxwell Demon Exist During Some Cognitive Processes

In several publications on "the learning brain", we have published EEG records showing a transition of alpha activity from a disordered state to an ordered state as cognitive loading on the Brain increases and, accordingly, the degree of working memory during the learning process. In one experimental scenario, the subject pays attention to three auditory or visual signals occurring at regular intervals. The task of the subject is the mental detection of the time of the fourth signal, which is omitted. At the beginning of the experiment, the subject's pre-stimulus alpha activity has low amplitudes and the 10 Hz oscillatory shapes are less regular. However, in the second stage of the experiment, the subject's pre-stimulus alpha manifests high amplitudes with regular, almost sinusoidal shapes, and a very good phase locking prior to the omitted stimulation. This means that the 10 Hz activity goes from a disordered state to an ordered one, i.e. from a *high entropy state to a low entropy state*. (See Fig.4)

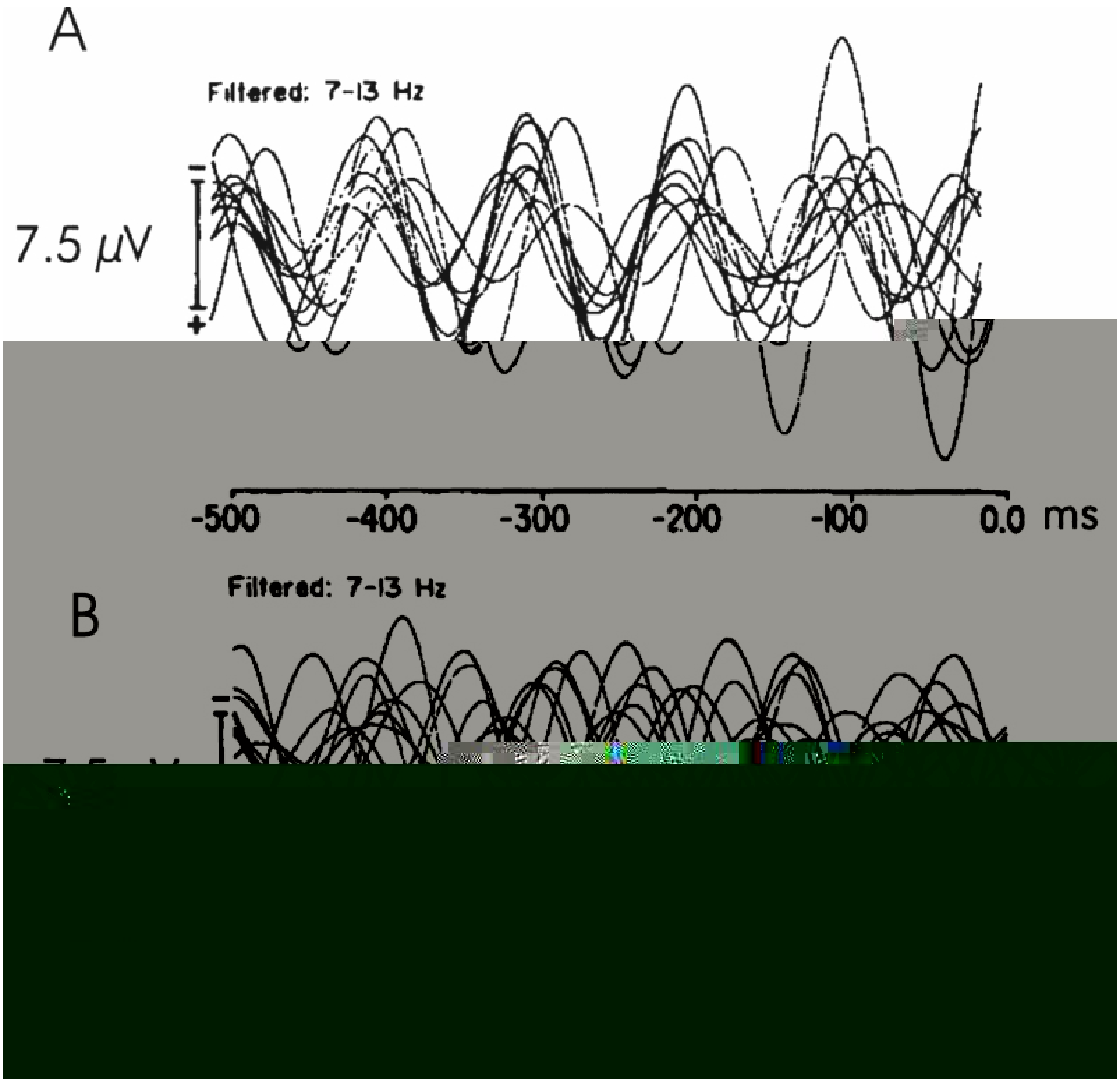

Figure 4. Vertex recordings in a 'repetable pattern formation' experiment (a) Approximately 10 prestimulus EEG sweeps at the end of the experiment (filter: 7-13 Hz). (b) Approximately 10 prestimulus EEG sweeps at the beginning of the experiment (filter: 7-13 Hz). (Modified from Başar et al., 1989, in Brain Dynamics, Springer, Berlin, p.43.)

In these experiments, prior to the omitted stimuli, no physical input to the brain was applied. However, during that thought process, the brain does decrease the entropy of the electrical activity. Visual observation of a recording of the alpha activity in the EEG indicates that regular alpha activity was observed at the end of the experiment. In other words, during "thinking processes" the brain's electrical activity exhibits a potential form of the Maxwell Demon scenario, which triggers the brain to violate the second law of thermodynamics. Let us assume that, during problem solving or high level of attention, processes leading to creative evolution the entropy law would be changed. If this assumption is tenable, the creative evolution within the brain would put the universe of human beings in a new dimensional state. Higher mental activity would be a key to change not only the structural form of oscillatory activity but, as a consequence, also the morphology of a number of brain structures, according to rules of Hebb (1949).

The second law of thermodynamics is valid for closed systems. The question is now, whether the brain can be considered as a closed system, despite the great number of stimuli from the milieu exterior. The same question is also valid for the entropy measurements described in the decrease of alpha in section 2 and figure 2.

In order to address this question, we repeated the same cognitive paradigm with Alzheimer patients who are unable to perform difficult cognitive tasks. These subjects did not show a similar entropy decrease in alpha to that observed in healthy subjects, although the milieu exterior was the same.

In conclusion, it can be said that there are three types of entropy decreases in the 10 Hz activity in various species and the human brain. All these three types of developments of alpha activities have a common dominator: In all three cases, the augmentation in the ability of thinking or cognitive processes is in accord with the entropy decrease. Also a parallel process with the decrease of anatomical entropy in all the studied brains is observed. According to these empirical results, we pose the following relevant questions: (1) Do brains that start to be tackled already with thought processes induce also entropy decreases in electrical signals and the anatomical shape or *vice versa* does the decrease of entropy in anatomical structure result in decrease of the entropy of electrical entropy and ensue the augmentation of cognitive processes and in the human brain the eliciting of intuition? (2) Are these three types of processes (entropy of electricity, entropy of anatomical organization and degree of thinking processes) in mutual interaction? Do they occur in parallel? It is not possible to identify a clear causality for their origin. It is possible that all three types of processes present a recurrent form of development. If we consider the brain dissipative structures start oscillations may also results in structural changes Prigogine (1980).

5 Hebb, Kandel and Edelman: Entropy Changes

5.1 Hebb's Theory: Growth of Neural Assemblies

In 1949, Hebb published a theory of perception and learning, in which a rapprochement was proposed between 1) perceptual generalizations; 2) the permanence of learning, and; 3) attention. It was proposed that a repeated stimulation of specific receptors will lead slowly to the formation of an "assembly" of association area cells which can act briefly as a closed system after stimulation has ceased. This process prolongs the time during which the structural changes of learning can occur and constitutes the simplest instance of a representative process (image or idea). Furthermore, according to Hebb, the interrelationships between cell assemblies are the basis of temporal associations of temporal organization in central processes (Attention, attitude, thought, so on).

Is there some kind of modification in neurons, or in connections between neurons, that takes place as a result of something being learned (Hebb, 1949)? For example, when we learn to associate two stimuli (e.g. an unconditioned stimulus and conditioned stimulus, as in classical conditioning), what exactly happens in the brain to support this process (Tranel and Damasio, 1995). Hebb (1949) proposed that the co-activation of connected cells would result in a modification of weights, so that when the presynaptic cell fires, the probability of the postsynaptic cell firing is increased. Hebb stated:

"When an axon of a cell A is near enough to excite cell B or repeatedly or persistently takes part in firing it, some growth or metabolic change takes place in both cells such that A's efficiency, as one of the cells firing B, is increased." (Hebb, 1949, p. 62).

This learning principle proposed by Hebb did not describe what was meant by "growths" or "metabolic changes". However, this principle served as a useful pioneering idea, and has become one of the widely cited concepts for neurobiological investigations of learning and memory. It is clear that increased connectivity between neural assemblies would increase synchrony and regularity of responses, thus manifesting a decrease of entropy.

5.2 Fundamental Results by Kandel Supports Hebb's Theory

Important advances in the understanding of learning and memory at the molecular level have come from the work of Eric Kandel and his colleagues (e.g. Kandel and Schwartz, 1982; Hawkins et al., 1983). Much of this work was conducted using the marine mollusc *Aplysia califomica,* which has a simple nervous system composed of approximately 10,000 neurons. The neurons are unusually large and easily identifiable, making *Aplysia* far more convenient for cellular-level studies than are vertebrates with infinitely more complex systems.

Research by Kandel and colleagues provided the first steps for direct evidence that alterations of synaptic efficacy play a causal role in learning. Specifically, they discovered that behavioral habituation of the gill and siphon withdrawal reflex, a staple behavioral preparation in *Aplysia,* was mediated by a reduction in transmitter release at a defined synaptic locus (Pinsker et al., 1970; Castellucci and Kandel, 1974). In turn, these results supported the principle of Hebb. Later, Bailey and Chen (1983) showed that habituation was accompanied by alterations in the morphology of electrophysiologically identified synapses. These findings provided direct evidence for forms of synaptic plasticity that could provide the cellular and molecular basis for at least some forms of learning and memory.

5.3 Re-entrant Signalling: A Theory of Higher Brain Function (Scope of G.M. Edelman)

Edelman (1978) raised the following important questions: "Does the brain operate according to a single principle in carrying out its high-order cognitive functions? That is, despite of the manifold differences in brain subsystems and the particularities of their connections, can one discern a *general mechanism* or *principle* that is required for the realization of cognitive facilities? If so, at what level does the mechanism operate- cells, molecules, or circuits of cells?

According to Mountcastle (1976), the central problem for brain physiology is how to understand the actions of large populations of neurons, actions that may not be wholly predictable from properties of subsets". The central problem of the intrinsic neurophysiology of the cerebral cortex is to discover the nature of neuronal processing with the translaminar chains of interconnected cells (in columns). Edelman (1978) transforms these statements as follows: *"The main problem of brain physiology is to understand the nature of repertoire building by population of cell groups."* We have stated elsewhere that EEG-oscillations should be considered as building blocks or as belonging to primitive repertoires of brain physiology.

Edelman (1987) developed a theory of neuronal group selection. This theory assumes a genetic endowment of neuronal groups, such as the columnar modules of the cortex, with an inherent degree of *variability and plasticity* in their connections. They constitute the units of selection of the primary repertoire. By exposure to external stimulation and a Hebbian mechanism, certain groups of cells, which tend to fire together, will be selected by stimuli insofar as groups respond to them, and thus their connection will be strengthened (Figure 1.2). Some of those connections will make *recurrent or re-entrant* circuits that are an essential feature of the model and of its theoretical and computational elaborations (Tononi et al., 1992). Groups not selected will be crowded out by the competition.

According to Edelman (1978) *"re-entry" is dynamic* and can take place via multiple parallel and reciprocal connections between maps. "Re-entry" takes place between populations of neurons, rather than between single units. Neurons within a group tend to be strongly connected. At a higher level, the integration of perceptual and conceptual components is required to categorize objects

5.4 Remarks related to Hebb, Kandel and Edelman

As described in the previous sections, the theories of Hebb, Kandel and Edelman are interrelated and each indicate a transition from irregular states to regular states during sensory-cognitive processes. We interpret these interrelated scopes as a "*decrease of entropy*" during learning process, as we hypothesized in the present section.

6 Is Hawking's Scope on Entropy Also Needed in Brain Research

In the 19th century, the French physicist Pierre Laplace (1878) suggested that, if the position and motion of all the particles in the universe known, Physics could predict the evolution of the universe into the future. Laplace formulated the ultimate version of classical determinism: that the behavior of a system depends on the behavior of its parts, and its parts obey deterministic law of Physics.

According to Heisenberg's uncertainty principle, the more accurately one tries to measure the position of a particle, the less accurately one can measure its speed and *vice versa*. The uncertainty principle had profound implications for the way in which we view the world.

The uncertainty principle signaled the refutation of Laplace's dream of a theory of science, a model of the universe that would be completely deterministic: One certainly cannot predict future events if one cannot even measure present state of the universe precisely. This view of Hawking was a discussion point in the understanding of the "Nebulous Cartesian System" (NCS) described by Başar and Güntekin (2007). The NCS presents a parallel situation to quantum mechanics, which does not predict a single defined result for an observation. Quantum theory introduces an unavoidable element of unpredictability or randomness into science. The wave particle processes may be neatly represented by the so-called "sum over histories", introduced by Richard Feynman. In this approach, the particle is supposed not to have a single history or path in space-time, as it would in a classical, non-quantum theory. Instead it is supposed to go from A to B by every possible path. The probability of going from A to B is found by adding up the waves for all the paths. This view has an important parallelism in studying brain waves. We have to study all the time histories or sum over histories of brain waves and of all settings in the vegetative system which is linked to the Brain with the cranial nerves. This again indicates that predictions in the brain-body incorporations have only a probabilistic nature (See Başar and Güntekin, 2009. See also Bergson in the companion report, Başar and Güntekin).

The laws of science do not distinguish between the past and the future. In any close system, the disorder (entropy) always increases with time; things always tend to go "wrong". The increase of disorder or entropy with time is an example of what is called an arrow of time - something that distinguishes the past from the future, giving a direction to time. There are at least three different arrows of time, the e direction of time, in which e-which disorder or entropy increases. Then there is the psychological arrow of time; this is the direction in which we feel time passes, the direction in which we remember the past but not the future. Finally, there is the cosmological arrow of time; this is the direction of time in which the universe is expanding rather then contracting (See Hawking, 2001).

We mention here the similarity or parallels with the concept of Bergson, who introduced the inhomogeneity of subjective time (See companion report, Başar and Güntekin).

7 Conclusions and a Tentative Synthesis

We return to the central question: The frequency code in brain oscillations remained almost unchanged during the evolution of species, as shown in Table 1 and indicated in several other publications. This poses the question, "What did change during evolution of species in electrical activity by assuming that the frequency codes were kept almost invariant?" As described by Başar and Güntekin (2009), four types of differentiations were observed, despite similar frequencies:

1) The amplitudes of slow EEG oscillations were increased from invertebrates toward the human brain, especially that of alpha activity (Section 2).
2) The synchrony of oscillations within a neural population also increased during evolution.
3) According to Bullock (1995), and Bullock and Başar (1988), no significant coherences were found in *Aplysia* neural networks, whereas in mammals and the human brain, large coherences between distant structures are recorded.
4) The entropy of electrical oscillations also diminishes during evolution. Strong evidence to support this can be observed in 10 Hz oscillations (See Table 1). (There are almost no 10 Hz oscillations observed in Helix Pomatia's Aplysia, land snails (*Helix potomia*) and sea slugs (*Aplysia*), whereas in the human cortex there are coherent and very regular 10 Hz oscillations).

From these four important differentiations, the decrease of entropy seems to have been a crucial factor during evolution from invertebrate ganglia to the human brain. Further, according to Hebb (1949), perceptual inputs or thoughts would increase the connectivity between neural assemblies. According to Edelman (1978), this can open the way to selective neural groups. Increased connectivity and building of selective neural groups would possibly induce a "greater order" in neural assemblies. In fact, the hippocampus, cerebral cortex and cerebellar cortex of mammals demonstrate regular cell-orders that are not encountered in invertebrates and lower vertebrates. For this reason, one can speak of a "*decrease of entropy*" in the shape of anatomical structures. On the other hand, the lower entropy of electrical oscillations (at least 10 Hz oscillations) shows a parallelism to the development of lower entropy of neural structures. This means that, during the evolution of species, the entropy of structural organization and of electrical oscillations is decreased. However, the second law of thermodynamics suggests the opposite; is the second law of thermodynamics thereby violated? During evolution and thought process only the existence of a Maxwell Demon can trigger the change of entropy. What might this "Maxwell Demon" be? Can "*thinking processes*" be considered as functioning like a Maxwell Demon? Humans are capable of displaying the highest levels of mental performance, including intuition, which leads to new discoveries or inventions. How might this decrease of entropy during evolution open the way to mental processes and, *vice versa*, are mental processes able to increase connectivity between neural populations, leading accordingly to modifications in ordered neural structures and regular alpha activity? Both ways are possible. One may even propose that both ways provide a recurrent and reciprocal activation of the incorporation of low entropy and higher nervous activity.

We return again to Bergson's *"creative evolution"* at the turn of the twentieth century (1907). Electrical activity of the brain, especially EEG oscillations and anatomical knowledge of neural structures were not yet discovered. Moreover, the theory of Hebbian neurons or the results of the maturation of the human brain were unknown. We must acknowledge the importance of Bergson's attempt to find parallelisms between the evolution of species and evolution of thought. It should also be emphasized that Bergson's association between the human brain and its capacity for intuitive solutions or creation is highly significant. Presently, we have biological and electrophysiological evidence to associate human brain and intuition. Also, the creative mind described by Blaise Pascal (1657) can be considered as a parallel concept to Bergson's theory of intuition.

The present essay is focused on the search for biological and electrophysiological correlates in evident changes of cognitive processes during evolution. We have at least three important evidences that are physiologically founded: the increase of alpha activity, the increased efficiency of cognitive processes, and the decrease of entropy. Two more findings support this strong statement: Before the age of three years, the child brain does not display either high cognitive processes or alpha activity. The mature brain has the capacity for higher cognitive processes and also displays alpha activity. During an experiment with cognitive loading, subjects depict low entropy and high amplitude alpha activity (See figure 4).

By viewing the chain of reasoning provided in this way, we somewhat force the boundaries of the brain's metaprocesses. We probably are able to open the way to attack the nature of intuition by means of modern methods. Modern methods of Neuroquantology are potentially able to lead to determining the nature of intuition.

Başar (2009) also surveyed the existence of 10 Hz activity in the spinal cord and in the smyphatic nerves of the heart. Accordingly the "alpha" was found to be not only a correlate of thought processes, but of fundamental functional body processes. This is also the case, since the visceral ganglia of invertebrates also have some kind of less regular and low amplitude 10 Hz oscillations. In other words, 10 Hz oscillation is a building block in all species for performing function and also forms a fundamental part of higher nervous function.

7.1 From Body-Brain to Mind

Başar and Güntekin (2007) and Başar (2008) assumed that the entire responsiveness of the brain is highly influenced by changes in the vegetative system, which is also embedded in the biochemical pathways (See figure 7, from Başar and Güntekin, 2007). The question "what is mind" and "what is conscious experiment" can be approached only by considering multiplicities in a hyperspace of measured parameters.

Therefore, Başar and Güntekin (companion report, in press) argued that, to understand "mind" it is necessary to determine functions defined as *"instinct", "intelligence" and "intuition"*. We point out that the work of philosophers from Aristotle to Descartes, Pascal, John Locke, Kant, Spencer and Bergson are extremely useful and relevant. However, in trying to describe "what the mind does" these prominent philosophers all lacked the benefit of current empirical, physiological and anatomical knowledge. Significant advances in these fields were made during the 20th century, and the level of scientific knowledge available in the 21st century now permits radically different approaches to investigation of such questions. The possibility of defining the expression "mind" is one step towards a global understanding of the brain, incorporating both instincts and phyletic memory.

According to Bergson, intuition is required to understand a problem and to solve it, which is often not possible by means of "intelligence". Furthermore, the creativity for which intuition is required can not be achieved only with simple intuitive behavior; Creativity can emerge only by combined effort of the "Brain-Body Integration" including memory, of the capacity for focused attention, knowledge, and rich episodic and semantic memories. The ability of association and speed of attention are also prerequisites for creativity.

8 What Is the Place of Bergson's Work in NeuroQuantology?

In the companion paper (Başar and Güntekin, in press) we surveyed the work of several scientists which proposed that theories of duration and time have several parallel frameworks with Heisenberg's S-Matrix, which is one of the essential mathematical constructs in quantum dynamics, and which also opened the way to Feynman Diagrams. The physical time (homogenous measurable time) and the durée (inhomogeneous and immeasurable time) of Bergson is in accordance with time concepts in quantum theory (see also Wiener, 1948).

In evolution theory, we are confronted with the concept of "*diminishing entropy",* which, in, turn, leads us to propose the existence of a "Maxwell Demon".

The relationship between Quantum Physics and Bergson's theory has been addressed by preeminent authors (Papanicolaou and Gunter, 1987). However, biologists and memory research scientists have yet to fully consider such issues within their fields. In both companion reports, we propose to initiate a debate considering Bergson's theories as a trailblazer in search of memory function, evolution of species, evolution of cognition and intuition. We feel that processing of brains alpha activity is a tenable example, and other empirical evidences may follow.

References

Bailey CH and Chen M. Morphological basis of long-term habituation and sensitization in Aplysia. Science 1983; 220: 91-93.

Başar E. EEG-brain dynamics. Relation between EEG and Brain Evoked Potentials. Elsevier: Amsterdam, 1980.

Başar E. Brain Function and Oscillations: I. Brain Oscillations. Principles and Approaches. Springer-Verlag: Heidelberg, 1998.

Başar E. Oscillations in "brain-body-mind"- A holistic view including the autonomous system. Brain Res 2008; 1235: 2-11.

Başar E. S-Matrix and Feynman Space-Time Diagrams to Quantum Brain Approach An Extended Proposal. Neuroquantology 2009; 7-1: 30-45.

Başar E and Güntekin B. A breakthrough in neuroscience needs a "Nebulous Cartesian System" Oscillations, quantum dynamics and chaos in the brain and vegetative system. Int J Psychophysiol 2007; 64(1):108-122.

Başar E and Güntekin B. Darwin's evolution theory, brain oscillations, and complex brain function in a new "Cartesian view". Int J Psychophysiol 2009; 71(1): 2-8.

Başar E and Güntekin B. Bergson's intuition and memory in view of neuroquantology. Neuroquantology in press.

Başar E, Başar-Eroğlu C, Röschke J, Schütt A. The EEG is a quasi-deterministic signal anticipating sensory-cognitive tasks. In: Başar E, Bullock TH (eds.). Brain Dynamics. Progress and Perspectives. Springer; 43-71: Heidelberg, 1989.

Başar E, Schütt A, Bullock TH. Dynamics of potentials from the brain of amniotes (vertebrates). In: Başar E (Ed.). Brain Function and Oscillations: II. Integrative Brain Function. Neurophysiology and Cognitive Processes; 109–116: Springer-Verlag, Heidelberg, 1999.

Başar-Eroğlu C and Başar E. A compound P300-40 Hz response of the cat hippocampus. International Journal of Neuroscience 1991; 60: 227-237.

Başar-Eroğlu C, Başar E, Demiralp T, Schürmann M. P300-response: possible psychophysiological correlates in delta and theta frequency channels. International Journal of Psychophysiology 1992; 13: 161-179.

Bergson H. L'évolution Créatrice. Presse Universitaires de France: Paris, 1907.

Bullock TH. Have brain dynamics evolved? Evol brain dynamics; 2-14: Brain Dynamics Workshop, Rancho Santa Fe, CA, 2002.

Bullock TH and Başar E. Comparison of ongoing compound field potentials in the brain of invertebrates and vertebrates. Brain Research Review 1988; 13: 57–75.

Bullock TH and McClune MC. Lateral coherence of the electrocorticogram: a new measure of brain synchrony. EEG and Clinical Neurophysiology 1989; 73: 479-498.

Bullock TH, Hofinann MH, Nahm FK, New JG, Prechtl JC. Event-related potentials in the retina and optic tectum offish. J Neurophysiol 1990; 64: 903–914.

Bullock TH, McClune MC, Achimowicy JZ, Iragui-Madoz VJ, Duckrow RB and Spencer SS. Temporal uctuations in coherence of brain waves. Proc. Natl. Acad. Sci. USA; 1995; 92:11568-11572.

Castellucci VF and Kandel ER. A quantal analysis of the synaptic depression underlying habituation of the gill-withdrawal reflex in Aplysia. Proceedings of the National Academy of Sciences 1974; 71: 5004-5008.

Darwin C. The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. London, 1859.

Darwin C. The expression of the emotions in man and animals. John Murray: London, 1872.

De Beer G. Darwin's notebooks on transmutation of species. Part II. Second notebook [C] (February to July 1838). Bull. Brit. Mus; 2, 75–118: Bull. Brit. Mus, London, 1960.

De Lamarck JB. Philosophie zoologique, ou Exposition des considerations relatives a l'histoire naturelle des animaux. Paris, 1809.

Descartes R. Discours de la méthode. Hachette: Paris, 1840.

Gebber GL, Zhong S, Barman SM. The functional significance of the 10-Hz sympathetic rhythm: a hypothesis. Clin Exp Hypertens 1995; 17: 181–195.

Gebber GL, Zhong S, Lewis C, Barman SM. Differential patterns of spinal sympathetic outflow involving a 10-Hz rhythm. J Neurophysiol 1999; 82(2): 841-54.

Edelman GM. Group selection and phasic reentrant signaling: A theory of higher brain functions. In: Edelman GM and Mountcastle VB (Eds.). The Mindful Brain. MIT Press; 51-100: Cambridge, 1978.

Edelman GM. Neural Danvinis. Basic Books: New York, 1987.

Hawkins RD, Abrams TW, Carew TJ, Kandel ER. A cellular mechanism classical conditioning in Aplysia: activity-dependent amplification of presynaptic facilitation. Science 1983; 219: 400-405.

Hawking S. The Universe in a Nutshell. Bantam Books: New York, 2001.

Hayek FA (Ed.). The Sensory Order. University of Chicago Press: Chicago, 1952.

Hebb DO. The organization of behaviour. Wiley: New York, 1949.

Kandel ER and Schwartz JH. Molecular biology of learning: modulation of transmitter release. Science 1982; 218: 433-443.

Laplace PS. Oeuvres complètes de Laplace. Gauthier-Villars: Paris, 1878.

Locke J. An Essay Concerning Humane Understanding. In Four Books. T Basset: London, 1690.

Maxwell JC. Theory of Heat. Greenwood Press: Westport, Connecticut, 1871.

Monod J. Le Hasard et la Nécessité. Editions du Seuil: Paris, 1970.

Mountcastle VB. The world around us: Neural command functions for selective attention. Neuroscience research Program Bulletin 1976; 14: 1-47.

Papanicolaou AC and Gunter PAY (Eds.). Bergson and Modern Thought: Towards a Unified Science. Harwood Academic Publishers: New York, 1987.

Pascal B. De l'Esprit géométrique. 1657.

Pinsker H, Kupfermann I, Castellucci VF, Kandel ER. Habituation and dishabituation of the gill-withdrawal reflex in Apbeia. Science 1970; 167: 1740-1742.

Prigogine I. From Being to Becoming: Time and Complexity in the Physical Sciences. Freeman: New York, 1980.

Rosso OA, Blanco S, Yordanova J, Kolev V, Figliola A, Basar E, Schürmann M. Wavelet entropy: a new tool for the analysis of short duration brain electrical signals. Journal of Neuroscience Methods 2001; 105: 65 – 75.

Schütt A, Bullock TH, Başar E. Dynamics of potentials from Invertebrate brains. In: Başar E (Ed.). Brain Function and Oscillations: II. Integrative Brain Function. Neurophysiology and Cognitive Processes; 91–108: Springer-Verlag, Heidelberg, 1999.

Smulders TV. Darwin 200: special feature on brain evolution. Biol Lett 2009; 5(1): 105-107.

Szilard L. Über die Entropieverminderung in einem Thermodynamischen System bei Eingriffe Intelligenter Wesen. Zeitschrift für Physik 1929; 53: 840 - 960.

Tononi G, Sporns O, Edelman GM. The problem of neural integration; Induced rhythms and short-term correlation. In: Başar E and Bullock TH (Eds.). Induced Rhythms in the Brain; 365-393: Birkhäuser, Boston, 1992.

Tranel D and Damasio AR. Neurobiological Foundations of Human Memory. In: Baddeley AD, Wilson BA, Watts FN (Eds.). Handbook of Memory Disorders; 27-50: John Willey and Sons, New York, 1995.

Wiener N. Cybernetics or Control and Communication in the Animal and the Machine. Massachusetts Institute of Technology: Massachusetts, 1948.