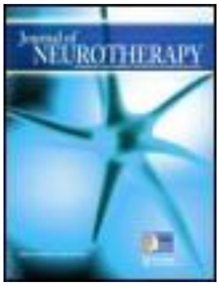

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A Review of: “Rhythms of the Brain, by György Buzsáki”

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RHYTHMS OF THE BRAIN. György Buzsáki. *Oxford University Press, New York, 2006, 464 pages, ISBN: 978-0-19-530106-9.*

György Buzsáki's book *Rhythms of the Brain* is an excellent review of the historical and modern neurophysiology of the human electroencephalogram (EEG). It is a scholarly work with hundreds of citations to peer-reviewed journal articles that span the last 80 years of the science of the neurophysiology of the human EEG. G. Buzsáki's contribution is exceptional in style and content in which chapter titles were replaced with "Cycles," and the order of the "Chapters of Cycles" begins with the very low frequencies of phylogenetic and embryonic development integrated with cycles nested in the awake and sleeping brain.

The science of the neurophysiology of the brain is where approximately 80% of the brain is excitatory and 20% inhibitory with elaborate reentrant loop structures mediated by refractoriness and the rhythmic bursts of action potentials from neurons located in particular brain structures such as the hippocampus, thalamus, and cerebellum. The coupled time cycles of all of the systems of the brain are integrated at each moment of time. The EEG is a measure of the mixture of the excitatory and inhibitory synaptic potentials that are excitability cycles in which increased excitability periodically occurs on the falling phase of a rhythm. There are significant refractory periods that give rise to stability and self-organization. The cycles of excitability are related to cycles of action potential burst activity, which is controlled by special synchronizing regions of the brain. Integration is accomplished by separate consideration of the "pacemaker" type activities of neurons in each of three brain structures (hippocampus, thalamus, cerebellum) as well as their intrinsic cyclic neurophysiology.

Another important contribution by Dr. Buzsáki is his emphasis on linking the science of phase reset and phase precession to the frequency spectrum of EEG rhythms. This is a critical and foundational linkage. The linkage is that the longer the duration of inhibitory burst activity in the thalamus then the slower the frequency of the EEG surface rhythms. This relationship was established by Steride and others with intracellular impalement of thalamic neurons and extracellular measures of current density and ionic channel dynamics related to the frequency spectrum of the human EEG. Phase reset was presented in the context of evoked potentials and the importance of the arrival time of inputs with respect to the intrinsic phase of an EEG rhythm. Dr. Buzsáki's in-depth analysis of phase reset and the importance of timing of the arrival of inputs to the phase of oscillators helped me and my colleagues to mathematically model surface EEG phase shift as a thalamic process in which high frequency bursts of thalamic inhibitory neurons advance EEG frequencies in local regions of the brain. Buzsáki shows why the thalamus is the multidimensional "pacemaker" that determines the frequency spectrum of the human EEG with the reticular formation being the master controller of the thalamus and responsible for the sleep–wakefulness cycle.

Another contribution is the integration of the concepts of 1/f or "one over frequency" with the structure of the human EEG including the concepts of "scaling" and "self-organized criticality." Chapter 5 covers these topics with clarity. The central idea of 1/f when plotted on a log–log plot is that there is scaling of energy as a function of frequency. Exponential fits to the 1/f distribution allow one to predict how a low frequency event can organize or affect high frequency components. The central idea of "self-organized criticality" is an activation–deactivation sequence of a "slow" energy addition and a "fast" energy dissipation with the additional condition of a preferred propagation direction and a limited range of energy dissipation and EEG phase reset meets these fundamental conditions of self-organized criticality.

Another noteworthy contribution by Dr. Buzsáki is his integration of the concepts and mathematics of "Small-World" models of the brain. The integration of tensegrity is interesting, although I personally found it difficult to fit such a rigid structure to the complex dynamics of ecological systems which are a fundamental aspect of the human brain. This aside the use of Small-World models is essential in understanding the phylogenetic and postnatal development of the human brain. The essence of the small-world model is that there are loops in the brain, and if one wants to find a specific individual neuron in a complex network of neurons, then what is the minimum number of connections necessary to find that individual neuron? The answer leads to the conclusion that the efficiency of a network increases by increasing the number of short-distance connections while reducing the number of long-distance connections. Buzsáki's nested cycles as chapters and nested concepts of cycles is unique and very effective in explaining crucial and fundamental concepts.

The style of *Rhythms of the Brain* is another unique feature, where the main body of each page is equation free. The narrative is clear and encompassing, and the reader is unburdened by citations in the text. This task is left to footnotes, which are laden with deep thoughts and important citations and often penetrating discussions of technical details. I strongly recommend reading all of the footnotes to more clearly understand the concepts in the body of the text, although the text itself is well written and descriptive.

An excellent contribution are the chapters that cover the hippocampus, the cerebellum, and the basal ganglia. These chapters reflect Dr. Buzsáki's personal history as a scientist who studied the neurophysiology of the hippocampus and cerebellum. These are insightful and integrative chapters (11–13) that show the neurophysiological basis of "pacemaker" type dynamics of neurons and the rhythms of these structures. An important insight is Dr. Buzsáki's repeated reference to the fact that the neocortex with its long-distance global connectivity is required to give rise to organized EEG patterns and rhythms. When the neocortex is removed and recordings are taken from the thalamus, then EEG rhythms are present but they are disorganized in space and involve uncoordinated bursting activity. These studies showed that the neorcortex driven by thalamo-cortical and cortico-cortical connections is what gives rise to organized and normal EEG patterns.

I obviously encourage anyone that is serious about understanding the EEG and the modern science of the EEG to read Dr. Buzsáki's book, *Rhythms of the Brain.*

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