Article

The Discovery of Quantum Tunneling in Biological Electron Transfer and the Possibility of a Redox-like Mechanism of the Mind: A Retrospective

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Abstract

This paper provides a brief personal recount of how an electromagnetic theory of psychology was born out of working in the lab of pioneers in biophysics. The story represents an example of how a useful macroscopically applicable cognitive theory may be derived from immersion in the study of microscopic molecular quantum principles. The example of the discovery and elucidation of quantum mechanical features of biological electron transfer in energy conversion by the author's mentors are discussed. It is suggested that the electrochemically charged reactions of oxidation-reduction (redox) in enzymes may be conceptually and physically analogous to processes in the brain. However, there are also important lessons learned and caveats about attempting to over-apply quantum effects that serve other purposes and are not likely to evolve into all components of a biological system. For example, a simple model of electron transfer rates that closely approximates a general biochemical law has proven to be a more useful and realistic metric than those that seek to find special quantum pathways in every part of the structure of the protein. Similarly, the author believes that an electromagnetic theory of consciousness based on sums of cellular electrochemical effects located primarily within the brain and body will ultimately prevail. Much work remains to show precisely how this is the case, but an initial explanation using redox principles is suggested.

Key Words: redox, quantum tunneling, electron transfer, mind, brain

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When I began my Ph.D. program in biophysics in the early 1990s at the University of Pennsylvania in the esteemed Johnson Foundation, nothing could have been further from my mind than spending a significant portion of the next seven years thinking about the mind. I had begun to do research in the lab previously headed by Britton Chance, an eminent emeritus professor credited with discovery of many aspects of the mitochondrial respiratory chain of enzymes, as well as discovering one of the first uniquely quantum-based processes in biology (Dutton, 2010). This was a biological mechanism of electron transfer over long distances that could only be explained by using a quantum tunneling mechanism (Devault and Chance, 1966).

My mentor, Les Dutton, the current director of the foundation, also did considerable work elucidating the biological factors and parameters influencing and guiding such long-range tunneling (Moser *et al.*, 1992), and is still a leader in

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understanding the thermodynamic properties of oxidation-reduction in enzymes and synthesized versions of them (Robertson *et al.,* 1994). For example, each part of the biological energy conversion process in photosynthesis and the mitochondria involves a cofactor such as a heme or other metal center, and each such way-station must have an electrochemical (electromagnetic) potential. So the measurement of this electric potential (Dutton, 1978) is critical information in calculating the energy converted and released in each step of energy transformation.

As I was becoming immersed in the ways and methods of such arcane research (see Haas *et al.,* 2001), I could not help but become almost "magnetically" drawn to their potential application to the human mind (the puns are unintended, although these metaphors were certainly used more than once during my time there). Making the situation most compelling, and at times bordering on annoying, were the constant metaphorical analogies and "anthropomorphism" of such redox mechanisms to human behavior. Perhaps in some way related to my mentor's unusual administrative style, whether intentionally meaningful or not, the molecules we were studying were constantly described in a scientific way using common psychological terms. For instance, the alignment of the amino acids seemed to be "choreographed," electron pathways required insulation so as not be "promiscuous" and toxic, and of course the electrons were supposed to move from their "negative" potentials toward the more "positive" endpoint. Such constant use and thinking about these principles ultimately led me to become convinced of their possible relevance to neuroscience and psychological behavior itself.

In my spare time during this period, and attempting to gain a broader knowledge than only this somewhat a-spiritual specialization, I began to consider how the physical principles of biochemistry-biophysics could be applied to mental life. My reasoning was that the brain must be made of these same sorts of component parts which are ubiquitous in biology (oxidoreductase enzymes in fact make up a large percentage of all enzymes), and that the bioenergetic principles of molecular biological life would probably extend to the organism as a whole. I would not be the first to believe that, as such a thermodynamic-like approach was first utilized by Freud, but I believed the electromagnetic model I was developing was unique and had a very good chance of being right. Of course, in the 1990s it was less common to hear use of electromagnetically tinged terms by the general public (i.e. "positive" and "negative," and "momentum"), and so I became utterly convinced of the importance of such a model and could not believe (and still can't) that it is not more generally appreciated that the brain and body are very likely to exist in internally charged states. This is to say, I believe the brain may be slightly charged when attracted or repelled from stimuli, and that individuals progress through a sequence of conversion of potential to kinetic energy throughout life, much like the bioenergetics underpinning energy conversion in mitochondria and photosynthesis.

In this respect, I would say these mentors and models I was surrounded and supported by during my doctoral training had an enormous influence on me. While immersed in their own particular areas of interest at the time, it is very likely I was in the right place at the right time, if a challenging one, in which I was able to think about beginning to extend their ideas to a higher level in biology and ultimately psychological behavior. Of course it is still early in my career and I have only recently begun to publish these ideas. But in the event that such a redox-like mechanism were to eventually prove true, I would certainly have to thank them.

I have also learned a great deal from the controversies I witnessed, in which I believe my advisor ultimately prevailed, that specialized quantum mechanisms usually involve approximations in biology, and there are limits to their application. For instance, it is not likely that electrons must follow special evolutionarily designed efficient pathways in the amino acid backbone of the protein itself (Moser *et al.,* 2010), because the backbone probably evolved primarily for structural purposes. Rather, the electrons are more likely to be conducted through optimally positioned metals (a true wire), while the intervening amino acids represent something closer to a statistical dynamic sum or a relatively uniform medium of many possible pathways (much like Feynman integrals, except not using special biologically evolved paths that may not really be necessary in most cases). Similarly, the tunneling never occurs once the distance surpasses a threshold where it becomes impossible (Page *et al.,* 1999). In this respect, I believe it requires great care in applying quantum principles to the gross behavior of an entire organ or organism, and it is one of the reasons why I prefer a generally thermodynamically based charge mechanism for the brain. This might be based on the collective electrochemical state of many neural cells, much like the redox potential of an enzyme must be measured by making the measurement on a large molar concentration of molecules.

More recently, I have studied and performed research in psychology at Harvard University, where my advisor is Professor Ellen Langer, a renowned thinker in the field of mindfulness (Langer, 2009). In her lab, I have finally been able to perform empirical studies on some of my behavioral science ideas, specifically focusing on the effects of mindfulness on interpersonal synchronization and "attraction." I believe this, like much psychological behavior, may involve physical processes at both the macroscopic and the most fundamental level. For instance, while physical synchronization of the mind and body with other individuals is a macroscopically experienced event, it must depend on detailed perceptual cues and cognition as well as being mediated by the biochemical components of the brain/body that calculate and coordinate it behind the immediate focus of conscious awareness.

However, it will remain a challenge to show that the underpinnings of these psychological processes can indeed be correlated directly (in a reductionistic way) with the fundamental principles of biological physics and chemistry themselves in the brain and body. Proving this will remain the goal of future work that will be pursued as I begin to grow beyond the mentorship I have received. Toward this end, I have recently begun to publish some of the theoretical ideas central to my physical psychoanalytic model (Haas, 2011; Haas, 2010a; Haas, 2010b). In the near future I also anticipate the completion of a comprehensive book on this new approach called "psychobiophysics" (please note that I use this word differently than others, as it is intended to denote a psychological model derived from the principles of the long-established multidisciplinary science of biophysics, rather than implying strange psychical forces).

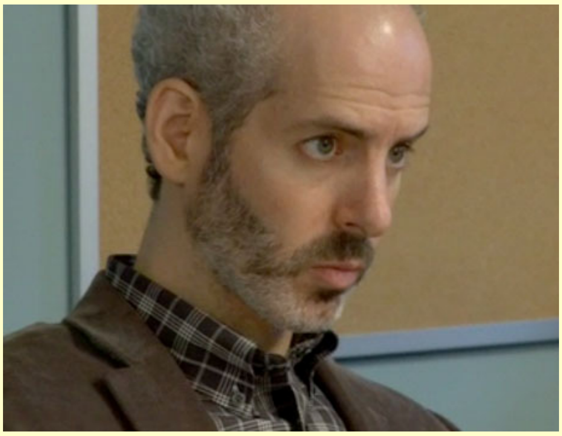
Only time will tell whether an electromagnetically based model of psychology can be empirically shown to be valid. In this regard, it may be helpful to understand how the model originated from some of the most rigorous experimentally tested principles of molecular bioenergetics and the mechanisms of biological oxidation-reduction. But of course a psychological theory must be mechanistically different than a molecular science in many ways, as it must incorporate the organism's gross biological properties and utilize the established preexisting principles of psychology and neuroscience. Nevertheless, I believe it is important to illustrate how training with a variety of highly reputable mentors in multiple disciplines can provide the scientific grounding, sophistication, and the role models that are often required for developing a new theory. From this perspective, it becomes easier to understand how it might be possible to develop a complex new model and to begin branching out in interesting new directions.

All of this certainly does not guarantee that any such hypothesized model is correct. Much work will need to be done to show how the cells and enzymes involved in cognition may exist in net electrochemically charged states. I have already offered some preliminary suggestions for this (see Part II of Haas, 2010a). Further, it is also already well-known that the surface of the body and brain itself are often polarized and exhibit just such small potentials (as measured by EEG, for instance). Therefore, I predict it is only a matter of time before this will be shown for the internal functional states of groups of cells within the brain itself and for the net charged states associated with thought and behavior.

A most obvious initial theoretical answer could be based on the fact that, as routinely observed using MRI, active areas of the brain use greater amounts of oxygen in their mitochondria than other areas. As oxygen is a considerably more positively charged electron transfer acceptor (+820 mV) than the original sources of electrons from metabolism (*e.g.,* NADH, -320 mV), it makes sense that the net result would be a positive one. However, this is assuming the creation of ATP (Abrahams *et al.,* 1994) and subsequent cellular events do not completely negate the trend. Thus, a more extensive analysis using this line of reasoning will be needed, but could quite feasibly answer a major part of this question.

I hope this biophysical problem in neuroscience will be explored further. It is with great eagerness that I look forward to presenting a new cognitive-behavioral model that takes advantage of this new physical scientific understanding of the mind. Ideally, this would be in a way that can be directly pragmatically useful to individuals in everyday life.

About the author



Dr. Haas trained in distinguished laboratories and formally studied biophysics/biochemistry, physics, molecular biology, and psychology. He is currently performing an experimental study of Jung's synchronicity effect to provide support for his theoretical scientific ideas. His doctoral thesis involved the generation of an electrical current by the mitochondrial enzyme that converts energy using oxygen. Alan also practices yoga and mind-body fitness, and enjoys hiking and weight training. Additionally, he was an All-American trombonist and has studied classical music performance.

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