Experiences in the Biocontinuum

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A New Foundation for Living Systems

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Dedicated to my Family for their patient tolerance

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PREFACE

In his 1962 landmark work entitled *The Structure of Scientific Revolutions,* Thomas Kuhn describes the true progression of scientific understanding as arising from revolutionary paradigm shifts in thought rather than as an evolving common wisdom built on the slow grind of systematic discovery (Kuhn, 1962). For the past 100 years, many scientists have considered the discipline of biology to be really ripe for such a paradigm shift. With new developments in the fields of nonequilibirum thermodynamics, systems theory, chaos, and information theory over the past few decades, there has been considerable interest in finally answering the question first posed by Erwin Schrödinger in the 1940s concerning the true scientific nature of living systems (Schrödinger, 2012). Similarly, there is also a growing interest within the biologic community for a more holistic and non-reductionist approach. However, the efforts in most current books and scientific literature have either lacked quantitative rigor or otherwise rely too heavily on traditional physics-oriented analytic platforms. The ideas expounded in this book build on the advancements of Francisco Varela, Stuart Kauffman, Robert Rosen, and many others by integrating elements of their perspectives under a singular unifying concept that is proposed to be the fundamental process of living systems. *At its core, the foundation of life is an experiential process leading to a meaningful and actionable knowledge acquisition and assimilation for the objective of survival within the biocontinuum of its environment.* The approach proposed herein is built on information theory and semiotics while including basic thermodynamic considerations and systems theory.

But the premise presented is much more than the simple exposition of a new hypothesis. This book describes the logical progression of thought based on established scientific ideas that was used in the conceptualization of the process and mathematical system that can be employed as a novel analytic framework for the study of living systems. As a part of this building effort, a wide range of diverse concepts and background information is first explored from the unique perspective of the question under consideration. The text is heavily peppered with source references to give context to the described ideas and provide credit to their origins. These references also hopefully provide a starting point for investigating some of these ideas in greater depth.

In the final third of the book, there is an amalgamation of these disparate concepts into an information-theoretic analytical construct for examining the foundations and dynamic processes of living systems. The geometric manifold and underlying mathematical algorithms of the replicator dynamics instantiated with this information-theoretic basis serves as an action functional of infometrodyanmics for living systems. Examples are provided that employ this framework in the analysis of some interesting aspects of living systems such as evolutionary processes and thermodynamic balances.

While this work really represents a sharing of my personal journey, my hope is that it would more generally appeal to those that are interested in systems biology, evolutionary mechanisms, theoretical bioengineering and the application of complexity theory to understanding the workings of living systems. And beyond the scientific implications of these findings, I would also encourage the novice to examine these concepts for a deeper understanding of the underpinnings of life. While we typically silo our focus of scientific investigation into the general areas of physics, chemistry, biology, etc., Science itself does not draw any such lines of distinction. In the final chapter entitled "Speculations", some abstract ideas are explored by using this foundational living system platform as a starting place for the unification of a variety of scientific questions from the perspective of a common denominator, the experience of first person participatory observers seeking knowledge. After all, in the final analysis we all are just wanting to understand.

CHAPTER 1

INTRODUCTION

The task is, not so much to see what no one has yet seen; but to think what nobody has yet thought, about that which everybody sees.
—Erwin Schrödinger

Foundations of Life

Since the beginning of recorded history, humans have reflected on their place in the Universe and the meaning of life. This self-examination has taken us from a journey inward to explore the nature of mind and soul and then further to an outward voyage of discovery through science in observing the workings of the Universe around us. And on this path we have occasionally stopped to inquire "What is Life?" recognizing that if we first understood the answer to this fundamental question then maybe the rest of the answers would follow (Weber, 2010). But the problem always proved insurmountable and the essence of life has seemed to be so elusive and different from anything else we ever encounter in the world. So until recently we have always retreated to a position of the mysterious when considering the true foundations of life and implicitly relied on some form of an "élan vital" to satisfy the enigmatic chasm in our comprehension.

In 1943 in a famous address at Trinity College in Dublin the respected Nobel Prize winning quantum physicist Erwin Schrödinger declared that the question of the nature of life is indeed a scientific problem and pointed to the basic laws of physics and the principles of thermodynamics as the potential solution (Schrödinger, 2012, 67-85) (Weber, 2010). This historic declaration was shortly followed by the discovery of DNA as life's blueprint by Watson and Crick which was then further enlightened by Monod's mechanistic explanation of gene regulation (Monod, 1997) (Cobb, 2017). During this same period, the thermodynamic description of opened dissipative systems was being advanced by Prigogine (Prigogine, 1961). These definitive Nobel Prize winning breakthroughs also coincided with a new understanding of nonlinear systems dynamics, advances in computer technologies and A. C. Guyton's quantitative analysis of basic physiologic

functioning (Guyton and Coleman, 1969, 1999) (Guyton, 1986). Interestingly, these ideas were additionally couched in the backdrop of the revolutionary paradigm shifts of modern science including Einsteinian Relativity Theory, Heisenberg's Quantum Uncertainty Principle and Gödel's Incompleteness Theorem (Wolf, 1981) (Penrose, 2004).

With these new conceptions about the basic working principles of natural phenomena, the old Newtonian/Copernican view of Nature came into serious doubt and once again a central role for the observer emerged. However, this time the observer was not pivotal to our world view simply because we are human or in any other way special. Rather the unique quality that once again placed the observer at the center of the Universe was that of merely being alive and having the capacity to experience the world. And with this capacity to experience, the observer also became a participator in the determination of reality.

Professor Schrödinger's enigmatic question of "What is Life?" was certainly salient in that for the first time the question was really asked from the perspective of a rigorous scientific inquiry (Weber, 2010). Schrödinger had recognized that the biologists' general description of life's characteristics (carbon basis, metabolic energetics, DNA informatics, cellular structure, etc.) or its common properties (growth, reproduction, respiration, etc.) were not enough for a real understanding of the essence of life. But he also knew that such a question needed a more fundamental approach and there should be an engagement of the notion of causality from first principles. Schrödinger suggested that thermodynamics would be a good starting point. And considering life's organization of matter, these basic physical principles are clearly essential for a fundamental understanding. What Schrödinger could not foresee were the forthcoming developments in the fields of information theory and nonlinear systems dynamics and the advent of advanced computational processing. With these new tools and the particular insights they bring to an analysis, we have begun to understand how complexity emerges in the organization of matter and the novel causal structures that are possible within living systems.

So the seeming magic of the élan vital is now possibly more understandable from an explicit scientific frame of reference. And the major lesson learned is that life is not just a "thing" so much but rather it is a process (Davies, 1993) (Davies, 2015). In fact, an emergence of this living process appears to be a natural consequence of an unfolding Universe (Kauffman, 2008). But the central process of life is not just any process such as the cycling of chemical reactions or the organizing procedures of crystal formation or even

the ostensible functioning independence of a tornado. While the same basic mechanics of these cited physical processes are all important in the successful operation of a living system, clearly none are the definitive root condition that differentiates a system as a living entity.

The essence of Life should be considered as a singular overarching process with a global scope and the capacity to generate its own being. And in doing so, living systems define the character of the Universe of which they are a part. In this way, living systems are not strictly subject to the causal whims of natural phenomena and should not be considered simply passive observers of Nature. Rather the role the living organism is as a participator in the Universe in a way that allows it to actualize its reality in the context of an objective toward its own subsistence. The quintessential process of life we are looking for is then the one that creates the coherence amongst all the other relevant necessary processes and provides for the emergence of the organized living system in a way that is in articulated harmony with its environment.

So the question advanced by Schrödinger is really about the nature of this fundamental guiding process that is required to create this capacity for global coherence, organization and articulation and is also necessary and sufficient for a system to be considered alive. The aim of this current treatise is to really explore this question of "What is Life?" with an emphasis on describing the unifying operations that make possible the condition of living in the view espoused above. ***The considered premise presented herein is that the fundamental capacity for experience and its integrated mechanism of knowledge acquisition as guided by the survival objective of the organism is the unifying principal process of living systems.*** In that central role, it is also proposed that this experiential process facilitates the mechanics of evolution and mediates a mechanism for the emergence of all knowable reality.

Reflecting on the title of this book, a foundation is defined as the fundamental basis for something. Typically the "something" that is considered as fundamental in the physical sciences is usually concerning its elementary constituent matter or the primary driving force involved. But as noted, life is a process so its foundation should be considered as the essential central process that is necessary and sufficient for its existence. As such, the experiential process is postulated to be the fundamental process and foundation from which all living systems should be deliberated in any scientific inquiry.

Building the Foundation

It is of little benefit to propose such a profoundly different paradigm of thought without first creating a solid framework on which to build ideas and establish the tools necessary for analyzing phenomena. Anything less would be simply philosophy or the domain of subjective speculation and good Science requires a more exacting and objective basis of operation for investigation and hypothesis testing. The cogent derivation of the procedures that can be used for a scientific investigation of living systems from a biocentric perspective can best be practically achieved with an explicit mathematical structure. Therefore, in order to develop such an experiential-based framework for scientific inquiry, it will be important to construct such a mathematical representation of the operational mechanics of biologic experience and knowledge acquisition by living systems. While it is understood from the work of Gödel that an axiomatic-based theory can never be considered entirely complete, mathematics is still the language of science because of its ability to provide the required specificity and logical consistency of thought (Gödel, 1931) (Hofstadter, 1980). In fact, the self-referential nature of biologic experience might provide further insights into the problems and limitations in the use of mathematics for constructing theories.

Besides the task of formulating the mathematical mechanics of the process of experience, many of the ancillary ideas presented in this book are intended to build the general rationale for the proposed theoretical configuration of the experiential framework. The goals of this proposed endeavor are quite broad and therefore require an understanding of a wide variety of disciplines from a very unusual and special perspective. It is quite probable that others with an advanced expertise in the areas of mathematics, thermodynamics or any of the other specialized fields of study addressed in this book will find much better ways of representing the concepts presented and expectantly extend these ideas far beyond those achieved in this current analysis. Hopefully, the framework offered in this present work can be employed to provide a basic understanding of the relationship between experimental observations and modern scientific theory from the new and unique perspective of the living system. While many established methods were used in developing a configuration for the experiential process, there was one salient principle that served as our primary guidepost in the formulation. It was considered that the new methodology for investigation posed herein must be consistent with the time-honored scientific method while providing a new and unique perspective from a biocentric viewpoint.

The specific aims of the current work are outlined below.

1. *Present a specific definition of life informed by certain acknowledged basic characteristics and qualities that are also consistent with current leading concepts.* The definitional description to be presented draws heavily on the work of Stuart Kauffman, Christine Skarda and Walter J. Freeman, Karl Friston, Alicia Juarrero, Mae Won Ho, Robert Rosen, and the Santiago school of thought. These works are referenced in the relevant texts and bibliography. As such, this definition is simple and concise but yet contains the crucial features that really characterize the elementary conditions of living systems. It is important to note that the intent of this work is *not* to create a new definition of life but rather to discern the key mechanism that allows living systems to have these distinctive characteristics and therefore differentiates the animate from the inanimate. The real point of first establishing a basic acceptable life definition is that it provides a blueprint which can be used to help guide the development of this new theory toward a central understanding of the most fundamental and essential property of living systems.

2. *Provide a special background for an understanding of the common scientific and mathematical concepts that will be used to formulate the proposed theory of the foundations of life.* Many of these concepts such as thermodynamics and nonlinear dynamics can be found in any general textbook concerning the discipline and many of the readers will have some prior knowledge about these topics. However, the nuanced views offered in this book about these subjects is couched from the special perspective of living systems and provides a basis and rationale for building some of the developed theories. Other infrequently encountered subjects, including information theory and replicator dynamics, may be less familiar to many readers. However, this material will be essential to understanding the broader theme of this book. Lastly, some of the other content that is explored pertaining to fields of study such as the Scientific Method and the more theoretical notions of knowledge, meaning and experience are intended to provide a contextual and definitional reference point for some of the discussions.

3. *Develop a proposed scheme for the natural emergence of life processes.* While the primary objective of the current work is not to determine the course for the origin of life, the exercise of following a likely pathway from which inanimate matter naturally becomes animate is useful in distinguishing the requisite components of the life process and delineating the principal mechanism that differentiates a system as

living. Each step of the scheme is founded on the logical progression of basic physical principles and scientifically feasible mechanisms previously described in the literature. The key tenet used in the overall derivation of the scheme was that each step and mechanism could plausibly arise naturally in a realistic physical milieu and must also rationally build toward an organized whole system functioning.

4. *Identification of the defining mechanism of living systems that provides for causal closure of the overall system scheme described above and is essential for the emergence of the global characteristics required in our definition of life.* In the stepwise building of the scheme for the natural emergence of life, each mechanism and process is evaluated as a necessary and sufficient condition. The purpose of this analysis is to ascertain if there is a specific mechanism that is manifestly essential and whose presence truly differentiates the system as being living. It is the central postulate of this book that the capacity for experience is the fundamental mechanism and process that distinguishes a system as living and enables the formation of a biocontinuum (to be defined in Chapter 2).

5. *Derive the mathematic and algorithmic mechanics of the experiential process from first principles.* If the experiential process is really at the core of what we call life, then it is important to construct a detailed model of that process. A model that has a mathematical and geometric structure will allow for a deeper understanding of the mechanics of experience and a prediction of the overall dynamics of the biocontinuum.

6. *Describe the causal loop that links the living system and its organized dynamic kinetics with orthogonal physical laws such as thermodynamics through the experiential process.* The interfacing of immutable physical principles with the ephemeral conditions dictated by nonlinear system dynamics is difficult to reconcile when considering the workings of living organisms. However, there is a cryptic interdependence between the classic characterization of energy forms that are needed to drive living processes and the life system structures created by these processes that are in turn then used to perceive and define the thermodynamic states. The causal loop that links these disparate entities is built through the experiential process.

7. *Explain how the causal relations in living systems come together to form the underpinning of the biocontinuum reality.* Formulating a causative connectivity between physical and kinetic constituents allows for a holistic perspective when considering the living system and its environment which together form the biocontinuum. Interestingly, the substance and dimensionality of these constituents is considered to be a product of the experiential process. The dynamics of these interactions shape an attractor from which the biocontinuum arises. For the condition of life and its experiential capacity to continue, the attractor must be sustained which in turn is consequently highly dependent upon the system's capacity for experience and actualization of the biocontinuum.

8. *Speculate how this process of experience in relation to the biocontinuum can be a basis for constructing a mathematical framework and general theory that can be used in the analysis of all natural phenomena.* The real power of any new system of thought comes from its use in originating novel and previously unforeseen ideas and by formulating an understanding of their mechanisms. The theoretical construct for experience devised in this book and its descriptive mathematical platform will be used to discern and analyze some basic notions about the foundations and the operations of living systems. This framework will also serve as the basis for some speculations regarding a variety of relevant subjects such as the mechanics of evolution and the role of living systems in the determination of observed dynamics for physical phenomena.

The March of Science

> *If I have seen further than others, it is by standing upon the shoulders of giants.*
> —Isaac Newton

This often repeated quote above by Isaac Newton is certainly true for almost any serious new scientific endeavor (https://www.brainyquote.com). The work presented herein is considered to be built on the many ideas and conceptions of a variety of brilliant thinkers over a spectrum of disciplines. While their works are referenced frequently in subsequent chapters, the broader contribution of their unique perspectives that has surely found its way into the formulation of the central thesis of this book is much more difficult to fully capture and attribute. In acknowledgment of that contribution, a list of individuals that have significantly impacted the work

presented in this book is found below in no particular order but with my special gratitude for their thoughts.

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Summary: A Unique Approach

> *But if the ultimate aim of the whole of science is indeed, as I believe, to clarify man's relationship to the Universe, then biology must be accorded a central position.*
> —Jacques Monod

An understanding of the Universe and all experienced phenomena should really begin with the origins of that experience which is contained within the processes of life itself. The approach to studying the foundations of living systems proposed in this book is decidedly different from those previously utilized or as is commonly presented in the literature. However, that is not meant to underestimate the value that those methods bring to our understanding of this subject. In fact, those traditional approaches are really the starting place for building the current perspective.

As stated above, the goal of this present work is to discover the singular integral property of living systems that naturally encompasses and empowers all other commonly cited attributes, properties and processes. Because of the comprehensive nature of this goal, the work draws on a variety of subject matter ranging from basic physics to integrative physiology. Furthermore, there is an intention to provide a structured mathematical framework that details the functioning of this property so that a logical and axiomatic analysis can be used for a deeper understanding of the fundamental essence of the living system. The general approach to

building this framework is from the perspective of an action functional based on thermodynamics and semiotic information metrics. Because this perspective is novel and somewhat more subtle in contrast to the traditional views, there is a great deal of attention given to some special nuances of the background concepts needed to build the theory. In many cases these traditional background topics are examined from an unfamiliar vantage point. Additionally, the reader should be warned that there is a considerable amount of purposeful repetition of key concepts from a number of different angles to provide further clarity to the unusual central ideas. This extensive attention to background basics and the reiteration of newly presented ideas is really considered part of the journey to understanding the unique and unifying conception of the experiential process as the foundation for living systems.

CHAPTER 2

BIOCONTINUUM

Every man takes the limits of his own field of vision for the limits of the world.
—Arthur Schopenhauer

Definition of a Biocontinuum

In the title of this book the unusual term "biocontinuum" is employed to describe the realm of experience and information regarding the state of being for living systems. While the component parts of the word (bio and continuum) are commonly understood, the true intended meaning of this unconventional portmanteau is undoubtedly not readily forthcoming through intuition alone. So it is necessary that this expression is clearly defined and explained as it plays an essential role in our central premise. In dissecting the word we know that "bio" means life. However, the term "continuum" is a little more difficult to define though we all instinctively know what it means. A continuum is generally considered as a continuous nonspatial whole or succession in which no portion of the whole is absolutely distinct from adjacent parts. The modern definition of the word has come to have an extension in meaning to denote the seamless union of entities into a whole such as the Minkowski mathematical framework that joins space and time into a single geometric structure called a continuum (Penrose, 2004). However, the continuum of space and time that we are interested in here is essentially one of experienced information and is also known as an information space.

An "information space" has been generally described by Newby as a set of concepts and the relations between them that are contained in an information system (Newby, 2001). In other words, a space containing a set of systematically interconnected pieces of information (McKay, 1972). Because of these systematic and logical interconnections, the space as a whole is considered to be coherent. Such a space then describes the range of possible values or meanings an entity can have under a given set of rules and conditions. In this age of computers and the internet we are accustomed

to encountering information spaces as we retrieve a file from our computer or use a search engine to find information on a website. What we are doing in these encounters is actively acquiring knowledge about the content within these spaces. But this is also what living systems are really doing during the process of experience. Through the experiential process they are actively acquiring knowledge through information concerning the content of a distinct space that is within the reach of their biologic perceptual capacity.

For the purposes of this current treatise, the proposed life biocontinuum is considered a coherent information space that includes everything that could have a potential experiential interaction and information exchange with the life system processes which are in turn responsible for generating, actualizing, and sustaining the conditions of the space. So that biocontinuum space includes all possible energy, material and informational exchanges as well as communiques originating from within or external to the usual considered boundaries of the organism. As a continuum, there is a no real distinction between the living system and its adjacent environment since the considered space includes everything within the experiential realm of the life processes. Including the organism's experience of its own internal state. The inseparability of the open living system from its environment, particularly with regards to exchanges in information, is becoming a common notion in modern theoretical constructs such as Evolutionary Game Theory where the replicators themselves are considered a part of the environment as a whole (Harper, 2011).

In summary, the biocontinuum is basically the realm occupied by the entire reach of a living system's experiential possibility. Since the living system is also in communication with the condition of its own state, that realm includes everything internal and external to the organism. All information from this space is then learnable with the boundaries being demarcated only by the limits of the living system's experiential capabilities. The process of experience and what that means will be described in much greater detail elsewhere in this book. But for current purposes we will simply define experience as the acquisition of knowledge from information that is available for perception and differentiation.

Purpose of the Biocontinuum Construct

The above conception of a biocontinuum makes sense with what we know about the physical reality of life processes. From physics we know that all closed systems must spontaneously and continuously move towards a progressive state of increasing disorder or entropy consistent with the 2nd

Law of Thermodynamics (Goldstein and Goldstein, 1993). By contrast, biological systems are known to be highly organized and through evolutionary processes tend to become more complex. Therefore, by inference from physical law, biological systems cannot be considered to be closed systems. These living systems are clearly open to exchanges of energy and matter and information with the space they occupy. In fact, the only real closure that distinguishes a biological system as a separate and distinct entity from its environment is its controlled organization and the horizon of informational exchange with that environment. As matter and energy are brought into the threshold of the organism and funneled into the organizing constraints of the living processes, the uncertain information concerning those elements is converted through the experiential process to a knowledge of the most probable order within the biocontinuum. Otherwise, all living systems are in complete material and informational continuity with their surroundings.

The rationale behind considering such a seemingly contrived frame of reference as this defined biocontinuum is that it brings a more comprehensive view of life's processes by binding the information of the external environment with the internal workings of the organism. After all, is not that what really happens anyway? The living system is actually seamlessly embedded in the reality of its surroundings and cannot really survive outside of its environment. Conversely, the external environment does not really have much dimensional form and meaning without the experiential context of the observer. So both the elements that are external and internal to the living system are inextricably interconnected and integrated and the primary reality is the whole of that biocontinuum space. Life then fundamentally becomes a vehicle for experience in which meaning is brought to this realm and the totality of substance and process are integrated. And that meaning originates from the context of the potential for sustained existence for that living system with a capacity for experience. To engage the central questions surrounding life and the emergence of its essential processes within the Universe, we will certainly require an understanding of the totality of its existence including the entire breadth of experience and influence within the biocontinuum space. The necessity for this approach will become clearer as we further developed our central premise.

Essence of the Biocontinuum

The biocontinuum as a conception of an information space for the experiential process has many similarities with David Chalmers' epistemic space developed in his study of consciousness (Chalmers, 1996). The epistemic space is considered the space of all possible *a priori* scenarios that are knowable as the state of that space. All information is then positioned in epistemic space in a way that governs how the world is seen and understood. This position does not deny the independent objectivity of the external world but only its importance relative to an understanding of its meaning for the living system. Within the biocontinuum, reality is actualized through its meaning to the living system because that system brings forth its constitution and dimensionality through the very act of perceptual experience. Without the experiential process and context of the living system, the configuration and attributes of the physical world cannot be practically distinguished and furthermore have no significant meaning particularly as it relates to the survival of the organism. Therefore, *knowable reality is a domain in space that is delineated epistemically or in terms of our meaningful knowledge about it, with the act of experience being the defining event*.

Knowledge acquisition reduces the scope of the space as information moves from that which is possible to that which is a certainty in the experiential realm. David Chalmers states that knowledge and belief divide the epistemic space which is really at the threshold of experience (Chalmers, 1996) (Chalmers, 2010). Mark Jago also notes that Chalmers's account of epistemic space does not include information which can be gained deductively from logical inference (Jago, 2009). That means that there are some possible scenarios that are naturally more likely than others based on prior experiences alone and can be logically inferred and deduced. But that inferred information could be considered a part of the belief component noted by Chalmers or a Bayesian prior engaged during the knowledge acquisition process.

From this perspective, the biocontinuum as described here not only includes the possible experienced knowledge space but also the combined information about the state of the observer which includes all inferences that can be derived from information and knowledge acquired through prior experiences. That information is really encoded within the observer's organizational system in the embodied form of its previously established structure and process dynamics. At the time of a new experience, that predicate state of the living system reflects the *a priori* predicted conditions

of the biocontinuum and the system's preceding adaptive conformation to those conditions in fulfilling its directive for sustaining its organization. So epistemic space is really considered just a component of the biocontinuum.

The major advantage of this conceptualization of the biocontinuum as a coherent information space of the entirety of the experiential realm is that it allows for the mathematical formulation of the possible states of the space in terms of Shannon information (Cover and Thomas, 2006). This information is first captured with perception and then differentiated and deconstructed to meaning as the process of knowledge acquisition is completed. With further ongoing experiences, a Bayesian process of updating through acquired knowledge can be used. This biocontinuum framework will serve us well when we track the general process of experience as an important element in the emergence of life.

Dimensionality and the Biocontinuum

The biocontinuum platform also lends itself to discussions regarding the measurement and analysis of physical phenomena and dimensions and the role of the observer. For example, the probability structures of statistical mechanics and quantum theory are likely born out of their epistemic chance nature and the difficulty of obtaining experiences of microscopic events (Wolf, 1981). Likewise, the position of the observer in the context of a unique observer's space-time continuum becomes the frame of reference in Einstein's relativity theory (Einstein, 1916, 1920). The basic concepts of energy and its qualification as work or disordered entropy in thermodynamic theory may also be dependent on the way changes occur within the biocontinuum and the differentiation of utility by the observer (Goldstein and Goldstein, 1993). The biocontinuum is a medium that is susceptible to being modified by physical energy exchanges which in turn results in an alteration in the state of the living system because of that system's sensitivity to perceiving changes in this medium. Through this differentiation of change and the subsequent discernment of its meaning by the living system, the quality of the energy exchange is determined and work is performed. But the accounting of any changes in the biocontinuum require some real dimensional metrics from which the information can be extracted.

A dimension is a geometrical/topological measure of an object's properties in terms of the number of points in a coordinate system that specify the object. It is within such a dimensional construct that objects can be distinguished or differentiated. It is also through this differentiation that the world becomes material to the observer/participator. According to the