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Review

What Is Information?: Why Is It Relativistic and What Is Its Relationship to Materiality, Meaning and Organization

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Abstract: We review the historic development of concept of information including the relationship of Shannon information and entropy and the criticism of Shannon information because of its lack of a connection to meaning. We review the work of Kauffman, Logan *et al.* that shows that Shannon information fails to describe biotic information. We introduce the notion of the relativity of information and show that the concept of information depends on the context of where and how it is being used. We examine the relationship of information to meaning and materiality within information theory, cybernetics and systems biology. We show there exists a link between information and organization in biotic systems and in the various aspects of human culture including language, technology, science, economics and governance.

Keywords: information; language; Shannon; biology; relativity; meaning; organization

1. Introduction

Information… arises… as natural selection assembling the very constraints on the release of energy that then constitutes work and the propagation of organization–Kauffman, Logan, Este, Goebel, Hobill and Shmulevich [1].

We have represented a discrete information source as a Markoff process. Can we define a quantity, which will measure, in some sense, how much information is 'produced' by such a process, or better, at what rate information is produced?–Shannon [2].

To live effectively is to live with adequate information–Wiener [3].

Information is a distinction that makes a difference–MacKay [4].

Information is a difference that makes a difference–Bateson [5].

We live in the Information Age and we are surrounded by information. Thanks to "new media" like the Internet, the Web, blogs, email, cell phones, iPods, iPads, eReaders, Blackberries and iPhones we are blanketed in information—drowning in information according to some.

In addition to this everyday interaction with information by the users of computer-based digital "new media" there is the role that information plays in the sciences of artificial intelligence (AI) and artificial life (AL). In AI intelligence is posited to be a form of information that can be downloaded from the human brain onto a computer. In AL life is posited to be a form of information that first became embodied in carbon-based chemicals but now can exist in silicon-based computers. Some AL scientists like Edward Fredkin [6] insist that the universe is a computer and that life including human life is merely a program running on that computer.

The irony of our total immersion in information as well as the prominent role it plays in AI and AL is that for the most part we do not really have a clear understanding of exactly what information is. Information is not a simple straightforward idea but rather it is a very slippery concept used in many different ways in many different contexts. Linguistically and grammatically the word information is a noun but in actuality it is a process and hence is like a verb. A consideration of the concept of information gives rise to a number of interesting questions.

Is there only one form of information or are there several kinds of information? In other words is information an invariant or a universal independent of its frame of reference or context?

What is the relationship of information to meaning and organization?

Is information a thing like a noun or a process like a verb?

Is information material or is it a form of energy or is it just a pattern?

Is information a uniquely human phenomenon or do non-human forms of life contain information?

What is the relationship of energy and information?

These are some of the questions we will address in this article as we try to flesh out our understanding of exactly what it is that we call information. We will consider the historic development of the concept of information to get a handle on the exact meaning of this thing or process that defines our age and is also the engine of economic growth. We trace the development of the concept of information from the earliest uses of the word to the beginning of information theory as formulated by Shannon and Wiener, to MacKay's [4] critique of Shannon information [2], to Bateson's [5] formulation of information as the difference that makes a difference to the inclusion of information in biotic systems. We also examine the relationship of information, energy and entropy arguing, as have many physicists before us, that information and entropy are opposites and not parallel as suggested by Shannon.

In attempting to answer the questions we have formulated above, we will review the work of Kauffman, Logan, Este, Goebel, Hobill and Shmulevich [1] that demonstrated that Shannon information does not fully describe the information contained in a living organism. Shannon information was developed to deal with how to transmit information with as few errors as possible and not with such concerns as meaning or evolution. We next introduce the notion of the relativity of information and show that the concept of information depends on the context of where and how it is being used. Next we will examine the relationship of information to meaning and materiality within information theory, cybernetics and systems biology. And finally we examine the link between

information and organization showing that in biotic systems that information and organization are intimately linked. We will also identify a similar link between information and organization in the various aspects of human culture including language, technology, science, economics and governance.

The literature on information theory is vast and it would be impossible to survey all of it. Two recent books that came out after the research reported here was completed is worth mentioning and that is *The Theory of Information: Fundamentality*, *Diversity and Unification* by Mark Burgin published in 2010 that provides an encyclopedic survey of information theory. The book *A Brief Review of Molecular Information Theory* by T. D. Schneider requires special mention because of the way in which Shannon information theory is used to study genetic systems and precisely characterize the sequence conservation at nucleic-acid binding sites. This seems to contradict our assertion that biotic information is different than Shannon information but as the reader will discover we are talking about different forms of information. The reader is also referred to this book that describes a relationship between energy and information.

2. Origins of the Concept of Information

We begin our historic survey of the development of the concept of information with its etymology. The English word information according to the Oxford English Dictionary (OED) first appears in the written record in 1386 by Chaucer: "Whanne Melibee hadde herd the grete skiles and resons of Dame Prudence, and hire wise informacions and techynges." The word is derived from Latin through French by combining the word inform meaning giving a form to the mind with the ending "ation" denoting a noun of action. This earliest definition refers to an item of training or molding of the mind. The next notion of information, namely the communication of knowledge appears shortly thereafter in 1450. "Lydg. and Burgh *Secrees* 1695 Ferthere to geve the Enformacioun, of mustard whyte the seed is profitable".

The notion of information as a something capable of storage in or the transfer or communication to something inanimate and the notion of information as a mathematically defined quantity do not arise until the 20th century.

The OED cites two sources, which abstracted the concept of information as something that could be conveyed or stored to an inanimate object:

> **1937** *Discovery* Nov. 329/1 The whole difficulty resides in the amount of definition in the [television] picture, or, as the engineers put it, the amount of information to be transmitted in a given time.
> **1944** *Jrnl. Sci. Instrum.* XXI. 133/2 Information is conveyed to the machine by means of punched cards.

The OED cites the 1925 article of R. A. Fisher as the first instance of the mathematicization of information:

> What we have spoken of as the intrinsic accuracy of an error curve may equally be conceived as the amount of information in a single observation belonging to such a distribution… If p is the probability of an observation falling into any one class, the amount of information in the

sample is $S\{(\partial m/\partial\theta)^2/m\}$ where $m = np$, is the expectation in any one class [and θ is the parameter] [7].

Another OED entry citing the early work of mathematicizing information is that of R. V. L. Hartley [8]. "What we have done then is to take as our practical measure of information the logarithm of the number of possible symbol sequences." It is interesting to note that the work of both Fisher and Hartley foreshadow Shannon's concept of information, which is nothing more than the probability of a particular string of symbols independent of their meaning.

3. Shannon and the Birth of Information Theory

Despite the early work of Fisher and Hartley cited above the beginning of the modern theoretical study of information is attributed to Claude Shannon [2], who is recognized as the father of information theory. He defined information as a message sent by a sender to a receiver. Shannon wanted to solve the problem of how to best encode information that a sender wished to transmit to a receiver. Shannon gave information a numerical or mathematical value based on probability defined in terms of the concept of information entropy more commonly known as Shannon entropy. Information is defined as the measure of the decrease of uncertainty for a receiver. The amount of Shannon information is inversely proportional to the probability of the occurrence of that information, where the information is coded in some symbolic form as a string of 0 s and 1 s or in terms of some α-numeric code. Shannon [2] defined his measures as follows:

> We have represented a discrete information source as a Markoff process. Can we define a quantity, which will measure, in some sense, how much information is "produced" by such a process, or better, at what rate information is produced? Suppose we have a set of possible events whose probabilities of occurrence are p_1, p_2, ..., p_n. These probabilities are known but that is all we know concerning which event will occur. Can we find a measure of how much "choice" is involved in the selection of the event or of how uncertain we are of the outcome? If there is such a measure, say $H(p_1, p_2,..., p_n)$… we shall call $H = p_i \log p_i$ the entropy of the set of probabilities $p_1..., p_n...$ The quantity H has a number of interesting properties, which further substantiate it as a reasonable measure of choice or information.

A story is told that Shannon did not know what to call his measure and von Neumann advised him to call it entropy because nobody knows what it means and that it would therefore give Shannon an advantage in any debate [9]. This choice was criticized by Wicken [10], who argued that in science a term should have only one meaning. Schneider and Sagan [11] referring to the use of the term entropy in both thermodynamics and information theory also suggests Shannon's use of the term is confusing when they wrote: "There is no simple correspondence between the two theories."

4. The Relationship of Information and Entropy

Understanding the efficiency of a steam engine through thermodynamics led Clausius to the idea of entropy as a measure of the mechanical unavailability of energy or the amount of heat energy that cannot be transformed into usable work. He referred to it in German as Verwandlungsinhalt, which may be translated roughly into English as "transformation content". Clausius then coined the term

entropy deriving the root tropy from the Greek word trope (τροπή) meaning transformation. He added the prefix "en" because of the close association he felt that existed between energy and entropy. One can therefore roughly translate entropy from its etymology as energy transformation. Clausius felt the need to define entropy because the energy of the universe is conserved but its entropy is constantly increasing.

The relationship between entropy and probability is due to the work of Boltzman from his consideration of statistical mechanics, which is an alternative way of looking at thermodynamics. He showed that the entropy of a gas is proportional to the logarithm of W where W is the number of microstates of the gas that yield identical values of the thermodynamic variables of pressure, temperature and volume. The formula he derived, namely, that $S = k \ln W$ where k is the Boltzman constant is what inspired Shannon to call his expression for the measure of information content of a message information entropy despite the difference in sign and the fact that the proportionality constant or Boltzman constant has the physical dimensions of energy divided by temperature.

The relationship between entropy and information as developed by physicists arose from a consideration of Maxwell's demon and is quite opposite to the one proposed by Shannon. Maxwell in 1867 postulated a gedanken experiment in which a demon standing in a doorway between two rooms filled with gas would allow only fast moving molecules to pass from one room to another so as to create a temperature difference in the two rooms from which usable work could be extracted in violation of the second law of thermodynamics. Leo Szilard in 1929 analyzing the problem that Maxwell's Demon presented showed that to obtain the information he needed the demon caused an increase of entropy elsewhere such that the net entropy did not decrease. He suggested that the demon is only able to temporarily reduce entropy because it possesses information, which is purchased at the cost of an increase in entropy. There is no violation of the Second Law because acquisition of that information causes an increase of entropy greater than the decrease of entropy represented by the information. As a result of Szilard's analysis one must conclude that entropy and information are opposite. He also pointed out that the net energy gained by the demon was not positive because of the energy cost in obtaining the information by which the demon selected the fast moving molecules and rejecting the slow moving ones. Since the information was purchased at the cost of an increase in entropy the information has an effective net negative entropy. Following Szilard, Gilbert N. Lewis [12] also saw an inverse relationship between information and entropy. He wrote, "Gain in entropy always means loss of information, and nothing more".

Schrödinger [13] in his famous and highly influential book *What is Life?* first explicitly introduced the notion of negative entropy:

> Every process, event, happening—call it what you will; in a word, everything that is going on in Nature means an increase of the entropy of the part of the world where it is going on. Thus a living organism continually increases its entropy—or, as you may say, produces positive entropy—and thus tends to approach the dangerous state of maximum entropy, which is death. It can only keep aloof from it, *i.e.*, alive, by continually drawing from its environment negative entropy—which is something very positive as we shall immediately see. What an organism feeds upon is negative entropy. Or, to put it less paradoxically, the essential thing in metabolism is that the organism succeeds in freeing itself from all the entropy it cannot help producing while alive (Chapter 6).

Both Wiener [3] and Brillouin [14] both adopted Shannon's definition of information and its relation to entropy with the one exception of its sign, likely influenced by the arguments of Szilard and Schrödinger [13].

Wiener [3] wrote,

> Messages are themselves a form of pattern and organization. Indeed, it is possible to treat sets of messages as having entropy like sets of states in the external world. Just as entropy is a measure of disorganization, the information carried by a set of messages is a measure of organization. In fact, it is possible to interpret the information carried by a message as essentially the negative of its entropy, and the negative logarithm of its probability. That is, the more probable the message, the less information it gives (p. 39)…. This amount of information is a quantity which differs from entropy merely by its algebraic sign and a possible numerical factor.

Brillouin [14] also argued that a living system exports entropy in order to maintain its own entropy at a low level. Brillouin used the term negentropy to describe information rather than negative entropy.

The reason that Wiener and Brillouin consider entropy and information as opposites or regard information as negative entropy follows from the tendency in nature for systems to move into states of greater disorder, *i.e.*, states of increased entropy and hence states for, which we have less information. Consider a system, which is in a state for which there is a certain finite number of possible configurations or microstates all of which are equivalent to the same macro state. The tendency of nature according to the second law of thermodynamics is for the number of microstates that are equivalent to the macrostate of the system to increase. Because there are more possible microstates as time increases and we do not know which particular microstate the system is in, we know less about the system as the number of possible microstates increases. It therefore follows that as the entropy increases the amount of information we have about the system decreases and hence entropy is negative information or vice-versa information is the negative of entropy. In other words the second law of thermodynamics tell us that when system A evolves into system B that system B will have more possible redundant or equivalent micro states than system A and hence we know less about system B than system A since the uncertainty as to which state the system is in has increased.

Wiener and Brillouin relate information to entropy with a negative sign whereas Shannon uses a positive sign. Hayles [6] notes that although this difference is arbitrary it had a significant impact. Observing that Shannon used the positive sign she also noted that "identifying entropy with information can be seen as a crucial crossing point, for this allowed entropy to be reconceptualized as the thermodynamic motor driving systems to self-organization rather than as the heat engines driving the world to universal heat death." For Wiener, on the other hand she wrote, "life is an island of negentropy amid a sea of disorder [6]."

Despite the difference in the sign of information entropy assigned by Shannon and Wiener, Shannon was heavily influenced by Wiener's work as indicated by the way Shannon [2] credits Wiener for his contribution to his thinking in his acknowledgement: "Credit should also be given to Professor N. Wiener, whose elegant solution of the problems of filtering and prediction of stationary ensembles has considerably influenced the writer's thinking in this field." Shannon also acknowledges his debt to Wiener in footnote 4 of Part III:

> Communication theory is heavily indebted to Wiener for much of its basic philosophy and theory. His classic NDRC report, *The Interpolation, Extrapolation and Smoothing of Stationary Time Series*, contains the first clear-cut formulation of communication theory as a statistical problem, the study of operations on time series. This work, although chiefly concerned with the linear prediction and filtering problem, is an important collateral reference in connection with the present paper. We may also refer here to Wiener's *Cybernetics* [3], dealing with the general problems of communication and control.

5. MacKay's Counter Revolution: Where Is the Meaning in Shannon Information?

According to Claude Shannon [2] his definition of information is not connected to its meaning. However, as Shannon suggested, information in the form of a message often contains meaning but that meaning is not a necessary condition for defining information. So it is possible to have information without meaning, whatever that means.

Not all of the members of the information science community were happy with Shannon's definition of information. Three years after Shannon proposed his definition of information Donald Mackay [4] at the 8th Macy Conference argued for another approach to understanding the nature of information. The highly influential Macy Conferences on cybernetics, systems theory, information and communications were held from 1946 to 1953 during which Norbert Wiener's newly minted cybernetic theory and Shannon's information theory were discussed and debated with a fascinating interdisciplinary team of scholars which also included Warren McCulloch, Walter Pitts, Gregory Bateson, Margaret Mead, Heinz von Foerster, Kurt Lewin and John von Neumann. MacKay argued that he did not see "too close a connection between the notion of information as we use it in communications engineering and what [we] are doing here… the problem here is not so much finding the best encoding of symbols… but, rather, the determination of the semantic question of what to send and to whom to send it." He suggested that information should be defined as "the change in a receiver's mind-set, and thus with meaning" and not just the sender's signal [6]. The notion of information independent of its meaning or context is like looking at a figure isolated from its ground. As the ground changes so too does the meaning of the figure.

Shannon, whose position eventually prevailed, defined information in terms of the transmission of the signal and was not concerned with the meaning. The problem with MacKay's definition was that meaning could not be measured or quantified and as a result the Shannon definition won out and changed the development of information science. The advantage that Shannon enjoyed over MacKay by defining information as the signal rather than meaning was his ability to mathematicize information and prove general theorems that held independent of the medium that carried the information. The theorizing that Shannon conducted through his combination of electrical engineering and mathematics came to be known as information theory. It is ironic that the OED cites the first use of the term "information theory" as that of MacKay's who used the term in a heading in an article he published in the March 1950 issue of the Philosophical Magazine.

Shannon's motivation for his definition of information was to create a tool to analyze how to increase the ratio of signal to noise within telecommunications. People that shared MacKay's position complained that Shannon's definition of information did not fully describe communication. Shannon

did not disagree–he "frequently cautioned that the theory was meant to apply only to certain technical situations, not to communication in general [2]." He acknowledged that his definition of information was quite independent of meaning; however, he conceded that the information that was transmitted over the telecommunication lines he studied often had meaning as the following quote from his original paper written at the Bell Labs indicates:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one **selected** from a set of possible messages. The system must be designed to operate for each possible **selection**, not just the one that will actually be chosen since this is unknown at the time of design. If the number of messages in the set is **finite** then this number or any monotonic function of this number can be regarded as a measure of the information produced when one message is chosen from the set, all choices being equally likely. [2]

I ask the reader to note that Shannon requires the number of possible messages to be finite as this will be a critical concern when we examine biotic information. I admire Shannon's frankness about his definition of information, which he devised to handle the engineering problems he faced. He was quite clear that his definition was not the unique definition of information but merely one definition of information suited for his engineering requirements. In the abstract to his paper, The Lattice Theory of Information he wrote,

> The word "information" has been given many different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field. The present note outlines a new approach to information theory, which is aimed specifically at the analysis of certain communication problems in which there exist a number of information sources simultaneously in operation [2].

What I find extraordinary is that his definition of information limited in scope by his own admission became the standard by which almost all forms of information were gauged. There have been some slight variations of Shannon information like Kolmogorov information more often referred to as Kolmogorov complexity used to measure the shortest string of 0 s and 1 s to achieve a programming result or represent a text on a computer or a Turing machine. But despite these small variations Shannon information has been accepted as the canonical definition of information by all except for a small band of critics.

I have purposely bolded the term selected and selection in the above quote of Shannon to highlight the fact that Shannon's definition of information had to do with selection from a pre-determined set of data that did not necessarily have any meaning. MacKay used this selective element of Shannon information to distinguish it from his own definition of information, which, unlike Shannon, incorporates meaning explicitly. He also defended his definition from the attack that it was subjective.

> Mackay's first move was to rescue information that affected the receiver's mindset from the "subjective" label. He proposed that both Shannon and Bavelas were concerned with what he called "selective information", that is information calculated by considering the selection of message elements from a set. But selective information alone is not enough; also required is another kind of information that he called "structural". Structural information indicates how selective information is to be understood; it is a message about how to interpret a message—that is, it is a metacommunication [6].

Structural information must involve semantics and meaning if it is to succeed in its role of interpreting selective or Shannon information. Structural information is concerned with the effect and impact of the information on the mind of the receiver and hence is reflexive. Structural information has a relationship to pragmatics as well as semantics where pragmatics tries to bridge the explanatory gap between the literal meaning of a sentence and the meaning that the speaker or writer intended. Shannon information has no particular relation to either semantics or pragmatics. It is only concerned with the text of a message and not the intentions of the sender or the possible interpretations of the receiver.

Part of the resistance to MacKay information was that its definition involved subjectivity, which orthodox scientists could not abide in their theories. Rather than deal with the fact that the exchange of information among humans involves a certain amount of subjectivity proponents of Shannon information theory chose to ignore this essential element of information and communications. Taken to its logical conclusion this attitude would limit science to study those areas that do not involve subjectivity, which would forever condemn linguistics and the other social sciences to non-scientific analysis. Rule out subjectivity in science or social studies and social science becomes a contradiction in terms.

This raises the question of whether subjectivity can be studied scientifically. I would suggest that an approach that parallels quantum physics is needed. Just as the measurement of sub-atomic particles changes their behaviour and requires a quantum mechanic representation that includes the Heisenberg Uncertainty principle, something similar is required for a science of the subjective—something I would call quantum rhetoric. What is the study of communications and media ecology after all but the study of how one set of subjective humans communicates with another set of subjective humans. Shannon successfully exorcised the subjectivity from communications, which was fine for his engineering objectives. I totally respect Shannon because he always warned that his definition was not intended to be a theory of communications. My problem is with those that misuse his work and over extend it.

6. Information: The Difference That Makes a Difference

Although Shannon's notion of information divorced from meaning became the central theme of information theory MacKay's counter-revolution was not without some effect and resulted in a slight shift in the way information was regarded. No doubt the reader is familiar with Gregory Bateson [4] famous definition of information as **"the difference that makes a difference."** Buried in this one-liner is the notion that it is the meaning of the information that makes the difference. Although Bateson gets credit for this idea it is likely that he was influenced by MacKay [3] who in his book

Information, Mechanism and Meaning published four years before the appearance of Bateson's one-liner wrote: **"information is a distinction that makes a difference."** Bateson, MacKay and Shannon were all participants in the Macy conferences so Bateson was quite familiar with MacKay's ideas. The use of the term "distinction" in MacKay's one-liner is more closely tied to the idea of "meaning" than the term "difference". It is ironic that MacKay who pointed out the shortcomings of Shannon information, was the first to use the term "information theory" and was the first to point out that the importance of information is its meaning and the fact that it makes a difference. MacKay is certainly a scholar who made a difference and he deserves more credit and attribution than he usually receives. And both MacKay and Bateson deserve credit for reminding us that meaning is a critical part of information and that Shannon's notion of information is not the whole story.

Another one line definition of information that incorporates the notion of its meaning is this one by Ed Fredkin which I would put in a league with Mackay and Bateson's one-liners. "The meaning of information is given by the processes that interpret it." This is a very insightful definition because it explicitly incorporates the notion that information depends on context.

If information is the distinction (McKay) or the difference (Bateson) that makes a difference then if there is no distinction or no difference then there can be no information. This would mean chaos or random numbers contain no information because there is no difference or distinction in one part of the stream of numbers as opposed to another part of the stream because of a lack of organization. This is opposite to the conclusion of Shannon who claims that a stream of random numbers contains the maximum information. While it is true each element is different from the next and is a complete surprise it is also true that the overall pattern of chaos and randomness is the same and hence there is no distinction nor is there any difference in the stream of random numbers. A gas, which remains uniformly at the same temperature, pressure and volume, is constantly changing but one cannot make a distinction between the gas at one moment and the gas at another moment. There is no difference in the way the gas behaves at these different moments. The only information one can discern about the gas is its volume, pressure and temperature, which is unchanging. No work can be done by this gas. If however in this volume of gas there is a temperature differential then work can be extracted from the gas and there is information in the gas by virtue of the way in which the temperature differential is organized. This raises the question of whether or not organization is information, a point we will return to later in this paper once we have dealt with the nature of information in biotic systems.

7. Information in Biotic Systems

We have seen that as early as 1925 the notion of information as an abstraction was first introduced by Fisher [7] and formalized by Shannon [2]. It was not long after this development that biologists also began to talk about information. The OED cites the first uses of the term in biology in 1953:

> **1953** J. C. ECCLES *Neurophysiol. Basis Mind* i. 1 We may say that all 'information' is conveyed in the nervous system in the form of coded arrangements of nerve impulses.
> **1953** WATSON and CRICK in *Nature* 30 May 965/2 In a long molecule many different permutations are possible, and it therefore seems likely that the precise sequence of the bases is the code which carries the genetical information.

The use of information in this context was not the mathematicization of information as was done by Fisher and Shannon but rather information was thought of qualitatively as something capable of being transferred or communicated to or through a living organism or stored in a living organism in the form of nucleic acid.

8. Life as Propagating Organization

Stuart Kauffman [15] defined an autonomous agent (or living organism) acting on its own behalf and propagating its organization as an autocatalytic system carrying out at least one thermodynamic work cycle. The relationship of the information found in living organisms to the kind of information treated in Shannon information theory was not clear even though a lot of attention has been given in recent times to the notion of information in biotic systems by those pursuing systems biology and bioinformatics. It was to examine this relationship that a group of us undertook a study to understand the nature and flow of information in biotic systems. This led to an article entitled Propagating Organization: An Enquiry (POE) authored by Kauffman, Logan, Este, Goebel, Hobill and Shmulevich [1] in which we demonstrated that Shannon information could not be used to describe information contained in a biotic system. We also showed that information is not an invariant independent of its frame of reference.

In POE we argued that Shannon's [2] classical definition of information as the measure of the decrease of uncertainty was not valid for a biotic system that propagates its organization. The core argument of POE was that Shannon information "does not apply to the evolution of the biosphere" because Darwinian preadaptations cannot be predicted and as a consequence "the ensemble of possibilities and their entropy cannot be calculated [1]." Therefore a definition of information as reducing uncertainty does not make sense since no matter how much one learns from the information in a biotic system the uncertainty remains infinite because the number of possibilities of what can evolve is infinitely non-denumerable. I remind the reader that in making his definition that Shannon specified that the number of possible messages was finite.

Instead of Shannon information we defined a new form of information, which we called instructional or biotic information, not with Shannon, but with constraints or boundary conditions. The amount of information will be related to the diversity of constraints and the diversity of processes that they can partially cause to occur. By taking this step, we embed the concept of information in the ongoing processes of the biosphere, for they are causally relevant to that which happens in the unfolding of the biosphere.

> We therefore conclude that constraints are information and… information is constraints… We use the term **"instructional information"** because of the instructional function this information performs and we sometimes call it **"biotic information"** because this is the domain it acts in, as opposed to human telecommunication or computer information systems where Shannon information operates [1].

A living organism is an open system, which von Bertalanffy [16] "defined as a system in exchange of matter with its environment, presenting import and export, building-up and breaking-down of its material components." Instructional or biotic information may therefore be defined as the organization

of that exchange of energy and matter. The fact that a biotic system is an open system can be used to argue against the association of instructional or biotic information with cybernetics because cybernetics focuses strictly on the flow of information and does not deal with the flow of energy and matter.

In POE [1] we argued that constraints acting as instructional information are essential to the operation of a cell and the propagation of its organization.

> The working of a cell is, in part, a complex web of constraints, or boundary conditions, which partially direct or cause the events which happen. Importantly, the propagating organization in the cell is the structural union of constraints as instructional information, the constrained release of energy as work, the use of work in the construction of copies of information, the use of work in the construction of other structures, and the construction of further constraints as instructional information. This instructional information further constrains the further release of energy *in diverse specific ways*, all of which propagates organization of process that completes a closure of tasks whereby the cell reproduces [1].

In POE [1] we associated biotic or instructional information with the organization that a biotic agent is able to propagate. This contradicts Shannon's definition of information and the notion that a random set or soup of organic chemicals has more Shannon information than a structured and organized set of organic chemicals found in a living organism.

> The biotic agent has more meaning than the soup, however. The living organism with more structure and more organization has less Shannon information. This is counterintuitive to a biologist's understanding of a living organism. We therefore conclude that the use of Shannon information to describe a biotic system would not be valid. Shannon information for a biotic system is simply a category error. A living organism has meaning because it is an autonomous agent acting on its own behalf. A random soup of organic chemicals has no meaning and no organization [1].

The key point that was uncovered in the POE analysis was the fact that Shannon information could be defined independent of meaning whereas biotic or instructional was intimately connected to the meaning of the organism's information, namely the propagation of its organization. Thus we see organization within a system as a form of information, which is a much more dynamic notion of information than Shannon information which is merely a string of symbols or bits.

According to Shannon's definition of information a set of random numbers transmitted over a telephone line would have more information than the set of even numbers transmitted over the same line. Once 2, 4, 6, 8, 10, 12 was received the receiver, who is assumed to be a clever person, would be able to correctly guess that the rest of the numbers to follow the sequence would be the set of even numbers. The random numbers have no organization but the even numbers are organized so the mystery of the relevance of Shannon information deepens as one must counter-intuitively conclude that information and organization can be at cross-purposes in Shannon's scheme of things.

This argument completely contradicts the notion of information of a system biologist who would argue that a biological organism contains information. It is by virtue of this propagating organization that an organism is able to grow and replicate, as pointed out by Kauffman [15] in *Investigations*. From the contradiction between Shannon and biotic information we already have a hint that there is

possibly more than one type of information and that information is not an invariant like the speed of light in relativity theory, which is independent of its frame of reference. We also see that perhaps Shannon's definition of information might have limitations and might not represent an universal notion of information. After all Shannon formulated his concept of information as information entropy to solve a specific problem namely increasing the efficiency or the signal to noise ratio in the transmission of signals over telecommunication lines.

9. The Relativity of Information

Robert M. Losee [17] in an article entitled A Discipline Independent Definition of Information published in the Journal of the American Society for Information Science defines information as follows:

> Information may be defined as the characteristics of the output of a process, these being informative about the process and the input. This discipline independent definition may be applied to all domains, from physics to epistemology.

The term information, as the above definition seems to suggest, is generally regarded as some uniform quantity or quality, which is the same for all the domains and phenomena it describes. In other words information is an invariant like the speed of light, the same in all frames of reference. The origin of the term information or the actual meaning of the concept is all taken for granted. If ever pressed on the issue, most contemporary IT experts or philosophers will revert back to Shannon's definition of information. Some might also come up with Bateson definition that information is the difference that makes a difference. Most would not be aware that the Shannon and Bateson definitions of information are at odds with each other. Shannon information does not make a difference because it has nothing to do with meaning; it is merely a string of symbols or bits. On the other hand, Bateson information, which as we discovered should more accurately be called MacKay information, is all about meaning. And thus we arrive at our second surprise, namely the relativity of information. Information is not an invariant like the speed of light, but depends on the frame of reference or context in which it is used.

We discovered in our review of POE that Shannon information and biotic or instructional information are quite different. Information is not an absolute but depends on the context in which it is being used. So Shannon information is a perfectly useful tool for telecommunication channel engineering. Kolmogorov [18] information, defined as the minimum computational resources needed to describe a program or a text and is related to Shannon information, is useful for the study of information compression with respect to Turing machines. Biotic or instructional information, on the other hand, is not equivalent to Shannon or Kolmogorov information and as has been shown in POE is the only way to describe the interaction and evolution of biological systems and the propagation of their organization.

Information is a tool and as such it comes in different forms just as screwdrivers are not all the same. They come in different forms, slot, square, and Philips—depending in what screw environment they are to operate. The same may be said of information. MacKay identified two main categories of information: selective information not necessarily linked to meaning and structural information specifically linked to meaning. Shannon information was formulated to deal with the signal to noise

ratio in telecommunications and Kolmogorov complexity was intended to measure information content as the complexity of an algorithm on a Turing Machine. Shannon and Kolmogorov information are what MacKay termed selective information. Biotic or instructional information, on the other hand, is a form of structural information. The information of DNA is not fixed like Shannon selective information but depends on context like MacKay structural information so that identical genotypes can give rise to different phenotypes depending on the environment or context.

Although we introduced the notion of the relativity of information in POE we were unaware at the time of the formulation of a similar idea long ago by Nicholas Tzannes [6] on page 56. He "wanted to define information so that its meaning varied with context… [and] pointed out that whereas Shannon and Wiener define information in terms of what it is, MacKay defines it in terms of what it does [6]." Both Shannon and Wiener's form of information is a noun or a thing and MacKay's form of information is a verb or process. We associate instructional or biotic information with MacKay as it is a process and not with Shannon because DNA, RNA and proteins are not informational "things" as such but rather they catalyze "processes" and actions that give rise to the propagation of organization and hence the transmission of information—information with meaning at that. Put simply instructional information is structural information as the root of the word instructional reveals.

In addition to the Tzannes' notion of the relativity of information we were also unaware that Mark Burgin also developed the notion even earlier in 1994 [19] and wrote of it again in 2010 [20].

Another distinction between Shannon information and biotic or instructional information as defined in POE is that with Shannon there is no explanation as to where information comes from and how it came into being. Information in Shannon's theory arrives *deus ex machina*, whereas biotic information as described in POE arises from the constraints that allow a living organism to harness free energy and turn it into work so that it can carry out its metabolism and replicate its organization. Kauffman [15] has described how this organization emerges through autocatalysis as an emergent phenomenon with properties that cannot be derived from, predicted from or reduced to the properties of the biomolecules of which the living organism is composed and hence provides an explanation of where biotic information comes from.

10. Information and Its Relationship to Materiality and Meaning

O, that this too too solid flesh would melt—Shakespeare's Hamlet (Act 1, Scene 2)
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?—TS Eliot
Where is the meaning we have lost in information?—RKL

To drive home the point that information is not an invariant but rather a quantity that is relative to the environment in which it operates we will now examine the relationship of information to materiality and meaning drawing on the work and insights of Katherine Hayles [6]. She points out that although information is used to describe material things and furthermore is instantiated in material things information is not itself material. "Shannon's theory defines information as a probability function with no dimension, no materiality, and no necessary connection with meaning. It is a pattern not a presence [6]".

The lack of a necessary connection to meaning of Shannon information is what distinguishes it from biotic information. Biotic information obviously has meaning, which is the propagation of the organism's organization. Information is an abstraction we use to describe the behavior of material things and often is sometimes thought of as something that controls, in the cybernetic sense, material things.

Hayles [6] traces the origin of information theory to cyberneticians like Wiener, von Forester and von Bertalanffy and telecommunication engineers like Shannon and Weaver. She points out that they regarded information as having a more primal existence than matter. Referring to the information theory they developed she wrote: "It (information theory) constructs information as the site of mastery and control over the material world".

She further claims, and I concur, that Shannon and cybernetic information is treated as separate from the material base in which it is instantiated. Wiener [2], for example, wrote in his book *Cybernetics, or Control and Communication in the Animal and the Machine* that "information is information, not matter or energy". The question that arises is whether or not there is something intrinsic about information or is it merely a description of or a metaphor for the complex patterns of behavior of material things. Does information really control matter or is information purely a mental construct based on the notion of human communication through symbolic language, which in turn is a product of conceptual thought as described in Logan [21]?

While it is true that the notion of information as used by the cyberneticians like Wiener, von Forester and von Bertalanffy and that used by Shannon and Weaver influenced each other and in the minds of many were the same they are actually quite different from each other. The notion of information as the master or controller of the material world is the view of the cyberneticians beginning with Wiener [3]: "To live effectively is to live with adequate information. Thus, communication and control belong to the essence of man's inner life, even as they belong to his life in society".

For communication engineers information is just a string of symbols that must be accurately transmitted from one location, the sender, to another location, the receiver. Their only concern is the accuracy of the transmission with the relationship to the meaning of the information being meaningless to their concerns. If we consider the relationship of information and meaning for the moment then there is a sense in which the cybernetician's notion of information has meaning as a controller of the material realm whereas Shannon information has no relationship as such to meaning. In fact one can question if Shannon's used the correct term "information" when he described $H = p_i \log p_i$ as the measure of "information". The quantity H he defined is clearly a useful measure for engineering in that it is related to the probability of the transmission of a signal—a signal that might or might not contain meaning. It is my contention that a signal without meaning is not truly information. I agree with MacKay and Bateson that to qualify as information the signal must make a difference, as is also the case with the way Wiener defines information in the context of cybernetics. Sveiby reports that Shannon himself had some second thoughts about the accuracy of his use of the term 'information':

> Shannon is said to have been unhappy with the word "information" in his theory. He was advised to use the word "entropy" instead, but entropy was a concept too difficult to communicate so he remained with the word. Since his theory concerns only transmission of signals, Langefors [22] suggested that a better term for Shannon's information theory would

> therefore perhaps be "signal transmission theory" (from the following Web site visited on 9/9/07: http://sveiby.com/portals/0/articles/Information.html#Cybernetics).

I find myself in agreement with Langefors that what Shannon is analyzing in his so-called information theory is the transmission of signals or data. It is consistent with some of my earlier work in the field of knowledge management and collaboration theory, in part inspired by the work of Karl Erik Sveiby, where Louis Stokes and I developed the following definitions of data, information, knowledge and wisdom:

- Data are the pure and simple facts without any particular structure or organization, the basic atoms of information,
- Information is structured data, which adds more meaning to the data and gives them greater context and significance,
- Knowledge is the ability to use information strategically to achieve one's objectives, and
- Wisdom is the capacity to choose objectives consistent with one's values and within a larger social context [23].

I also found the following description of the relationship of data and information that I accessed on Wikipedia on September 12, 2007 particularly illuminating:

> Even though information and data are often used interchangeably, they are actually very different. Data is a set of unrelated information, and as such is of no use until it is properly evaluated. Upon evaluation, once there is some significant relation between data, and they show some relevance, then they are converted into information. Now this same data can be used for different purposes. Thus, till the data convey some information, they are not useful.

I would interpret the signals transmitted between Shannon's sender and receiver as data. Consistent with MacKay and Bateson's position information makes a difference when it is contextualized and significant. Knowledge and wisdom represent higher order applications of information beyond the scope of this study. The contextualization of data so that it has meaning and significance and hence operates as information is an emergent phenomenon. The communication of information cannot be explained solely in terms of the components of the Shannon system consisting of the sender, the receiver and the signal or message. It is a much more complex process than the simplified system that Shannon considered for the purposes of mathematicizing and engineering the transmission of signals. First of all it entails the knowledge of the sender and the receiver, the intentions or objectives of the sender and the receiver in participating in the process and finally the effects of the channel of communication itself as in McLuhan's [24] observation that "the medium is the message". The knowledge and intention of the sender and the receiver as well as the effects of the channel all affect the meaning of the message that is transmitted by the signal in addition to its content.

11. The Meaning of Information in Biotic Systems

Biotic or instructional information, defined in POE as the constraints that allow an autonomous agent, *i.e.*, a living organism, to convert free energy into work so that the living organism is able to propagate its organization through growth and replication, is intimately connected with meaning. "For

Shannon the semantics or meaning of the message does not matter, whereas in biology the opposite is true. Biotic agents have purpose and hence meaning [1]". One can therefore argue that since the meaning of instructional information is propagating organization that we finally understand the meaning of life–the "meaning of life" is propagating organization. This remark is not meant to trivialize the great philosophical quest for the meaning of life from a human perspective but there is a sense in which the meaning of life including human life is indeed the propagation of organization. The purpose of life is the creation or propagation of more life.

In addition to the fact that Shannon information does not necessarily entail meaning whereas biotic or instructional information always entails meaning there is one other essential difference between the two. Shannon information is defined independent of the medium of its instantiation whereas biotic information is very much tied to its material instantiation in the nucleic acids and proteins of which it is composed. The independence of Shannon and cybernetic information from the medium of its instantiation is what gives rise to the notion of strong artificial intelligence and claims like those of Moravic, Minsky, and to a certain extent Wiener, that human intelligence and the human mind can somehow be transferred to a silicon-based computer and does not require the wet computer of the human brain. Shannon and cybernetic information can be transferred from one material environment to another, from one computer to another or in the case of Shannon information from one telephone to another or from a computer to a hard copy of ink on paper. This is not the case with living organisms in the biosphere where information is stored in DNA, RNA and proteins.

Shannon information whether on paper, a computer, a DVD or a telecommunication device, because it is symbolic, can slide from one medium or technology to another and not really change, McLuhan's [24] "the medium is the message" aside. This is not true of living things. Identical genotypes can produce very different phenotypes depending on the physical and chemical environment in which they operate. Consider the fact that identical twins are not "identical". The reason identical twins are not "identical" is that the environment in which the biochemical interactions between biomolecules takes place alters the outcome.

12. The Materiality of Information in Biotic Systems

Information is information, not matter or energy. No materialism which does not admit this can survive at the present day.–Norbert Wiener [2]

Shannon's theory defines information as a probability function with no dimension, no materiality, and no necessary connection with meaning. It is a pattern not a presence [6].

Shannon information cannot be, nor was it meant to be, naively applied to complete living organisms, because the information in a biotic system like DNA is more than a pattern—it is also a presence. A receptor for food or toxins is not just a pattern—it is also a presence. A biological system is both an information pattern and a material object or more accurately information patterns instantiated in a material presence. Schrödinger [13] long ago before the discovery of DNA described this dual aspect of chromosomal material metaphorically. "The chromosome structures are at the same time instrumental in bringing about the development they foreshadow. They are law-code and executive power–or, to use another simile, they are architect's plan and builder's craft–in one." It is the

dynamic of the interaction between the patterns of information and the material composition of the biotic agents that determines their behavior.

As previously discussed, the issue hinges on the degree to which one can regard a biotic agent as a fully physical computational system. It is clear that a biotic system cannot be described only by Shannon information for which the information is abstracted from it material instantiation and is independent of the medium. The same argument can be made for the inappropriateness of Kolmogorov complexity for biotic systems. Kolmogorov complexity, which is defined with respect to Turing machines, is another case where the information pattern is separated from its material instantiation. Biology is about material things not just mathematical patterns. As Kubie once warned at one of the Macy conferences, "we are constantly in danger of oversimplifying the problem so as to scale it down for mathematical treatment [6]". As noted above the physical environment changes the meaning of the information embedded in the DNA of the genome.

Another way to distinguish the difference between biotic or instructional information and either Shannon or Kolmogorov complexity is that the latter are symbolic which is not the case for biotic or instructional information. The information coded in the chemical alphabet of biomolecules that make up living organisms acts through the chemical interactions of those biomolecules. "DNA is a molecule interacting with other molecules through a complex set of mechanisms. DNA is not just some text to be interpreted, and to regard it as such is an inaccurate simplification [25]". It is not the symbolic nature of DNA that gives rise to messenger RNA and it is not the symbolic nature of RNA that gives rise to proteins but rather the chemical properties of DNA that produce or catalyze the production of RNA and the chemical properties of RNA that produce or catalyze proteins and the chemical properties of proteins that carry out the protein's various functions such as:

1. Serving as enzymes to catalyze biochemical reactions vital to metabolism;
2. Providing structural or mechanical functions, such as building the cell's cytoskeleton;
3. Playing a role in cell signaling, immune responses, cell adhesion and the cell cycle.

DNA, RNA and proteins are both the medium and the content, the message and the messenger. Not so for Shannon and Kolmogorov information where one can distinguish between the medium and the message, the message and the messenger. The message is the information, which operates independent of the medium in which it is instantiated, McLuhan [24] aside. For biotic information, on the other hand, the medium and the message are the same—they cannot be separated. For biotic information the medium is the message in the McLuhan sense and it is also the content. For human symbolic information described by Shannon information, the information or content and the medium are quite separate. For biotic systems not only is the medium the message in the McLuhan sense that a medium has an effect independent of its content but the medium is also the content because it is the chemical properties of the medium that affects the organism. In fact the medium is the message because it is literally the content and the content of the message is unique to that medium and is instantiated in it and it cannot be transferred to another medium. To repeat it is not possible to transfer the content or the message of the medium to another medium. There is an isomorphism between the medium and its content. The medium is the content and hence also the message. The medium is both the message and the content for a biotic system because information in a biological system is not symbolic but rather

chemical. It is for this reason that the notion of transferring the contents of the human brain to a computer is pure nonsense.

To conclude we have argued that information is not an invariant independent of the frame of reference in which it operates. In the biotic frame of reference information is always associated with meaning, which is not necessarily the case with Shannon or Kolmogorov information. In the biotic frame information cannot be separated from the medium of its instantiation as is the case in the Shannon and Kolmogorov reference frames. In other words the information in DNA, RNA and proteins are embodied. They differ from human symbolic information, which can be disembodied and moved from one medium to another. Each generation makes a god of their latest technological or scientific achievement or breakthrough. For the Hebrews it was the written word and the law "written with the finger of God". For the Greeks it was their deductive logic and rational thought disembodied from practical experience and empirical evidence of the physical world. For the Enlightenment it was Newtonian mechanics and God, the clock maker, where things were explained in terms of mechanical models. In the Information Age the god is disembodied information, information without context where everything is explained in terms of the transfer of information, and sometimes it is information without meaning.

13. Organization as Information

What is the relationship of organization and information? What we discovered in POE was that the autocatalysis of biomolecules led to the organization of a biological living organism whose organization of constraints allowed it to convert free energy into work that sustained growth and permitted replication. We identified the constraints as instructional or biotic information, which loops back into the organization of the organism. This model of information holds for biotic systems where autocatalysis is the organization and the components are the individual biomolecules.

The argument seems circular only because a living organism represents a self-organizing system. This is still another way that biotic information differs from Shannon information which is defined independent of meaning or organization. In fact organized information has less Shannon information because it does not reduce as much uncertainty as disorganized information. It is also the case as we mention above that this model provides a mechanism for the creation of information which in not the case with the Shannon model of information.

I believe that Hayles [6] has come to a similar conclusion regarding the relationship of information and organization when she wrote about the paradigm of autopoiesis or self-organization:

> Information does not exist in this paradigm or that it has sunk so deeply into the system as to become indistinguishable from the organizational properties defining the system as such.

It is the latter half of her statement that is congruent with our notion that the set of constraints or organization that give rise to an autonomous self-organizing system is a form of information.

Wiener like Shannon related information to entropy but, unlike Shannon, Wiener [3] saw a connection between organization and information, "The notion of the amount of information attaches itself very naturally to a classical notion in statistical mechanics: that of entropy. Just as the amount of information in a system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization".

We make a similar claim in POE [1] when we assert that the constraints that allow the propagation of organization in a living organism represents the information content of that organism. In other words the propagating organization of a living organism is its information content. Our position in a certain sense recapitulates similar sentiments expressed by Norbert Wiener [3] when he wrote "We are not stuff that abides but patterns that perpetuate themselves".

However where I differ from Weiner is that while we are patterns that abide I also believe that we are patterns that are uniquely instantiated in flesh. I therefore believe that human intelligence cannot be transferred from a human brain onto a silicon-based computer as is claimed by some advocates of strong AI. The point that I would make is that the pattern cannot be separated from the medium in which it is instantiated as was argued above. The medium of flesh and its organization are what is critical. It is the pattern instantiated in the flesh and not just the pattern by itself that makes life. The information in a biological system is not symbolic but rather chemical. As we have already asserted the medium of the flesh is both the message and the content of a biotic system.

14. Who Are We? What Are We, Information or Flesh?

Information in the form of words or language is symbolic. The word cat is a symbol that represents a class of living breathing creatures made of flesh. An actual cat is not a symbol of something else but an organization of organic chemicals that can propagate its organization through its metabolism and its ability to replicate.

The organic chemicals of which we are composed are continually replaced so that after seven years there is a completely new set of molecules. So we are not flesh or a particular set of molecules but the organization of the molecules of which we are composed or more accurately we are a process and not a thing that can be duplicated.

One cannot make a replica of a person. Even twins that originated from the same fertilized egg are never exactly the same. But a text can be replicated or duplicated exactly. A text can also be transmitted and reformatted from one medium to another, for example from a computer file to a text printed on paper or from a live performance to a podcast.

I believe that the proponents of strong artificial intelligence (AI) and strong artificial life (AL) make the mistake of considering intelligence or life as merely reified information. They do not take into account that it is the interaction or organization of flesh-based matter that makes intelligence and life. The pattern of that interaction or organization that we identify as information cannot be abstracted away from the physical medium in which it is instantiated and remain unchanged or, even more importantly, continue as the process that gave rise to that intelligence or life in the first place.

A feature of both intelligence and life is that it is autonomous. A living organism is an autonomous agent that has the capacity to exploit free energy from its environment and use that energy in the form of work to carry out its metabolism, to replicate and to make use of its intelligence. The proponents of strong AI and AL overlook this important factor when they claim that intelligence and life is nothing more than information or a pattern that is independent of its physical instantiation. At best artificial life forms may be regarded as obligate symbionts with humans but not as independent living organisms as they are not autonomous.

15. Human Language, Culture, Technology, Science, Economics and Governance as Forms of Propagating Organization

"I take informatics to mean the technologies of information as well as the biological, social, linguistic and cultural changes that initiate, accompany, and complicate their development [6]".

Katherine Hayles' quote indicates that there is a link between biological, cultural and linguistic information. It was also noted in POE that language and culture like living organisms also propagate their organization and hence their information. This also includes science, technology, economics and governance which are part of culture and will be treated separately because they provide vivid examples of propagating organization. The information that language and culture represent like biotic information is not Shannon or selective information but rather information with meaning, namely MacKay structural information.

Cultural and linguistic information is not fixed but depends on the context–as conditions change so do languages and cultures. This statement applies to the various sub-division of culture that we have explicitly identified, namely, science, technology, economics and governance. These forms of information do not represent Shannon selective information but rather MacKay structural information because of their dependence on context. Each one is more than a string of alphanumeric symbols or a string of 0 s and 1 s.

Let me provide an example of how linguistic meaning depends on context based on my experience of being the father of four children who in turn have provided me so far with four grandchildren. The meaning of the term Dad has changed for me over my lifetime. Dad used to be my father and then when I had children it meant me and then when my children had children and I became grandpa and Dad became the father of my grandchildren.

The point is that the meaning of words are context dependent. This is why I [21] identified words as strange attractors. They are strange attractors because the meaning of a word is never exactly the same as its meaning changes ever so slightly each time it is used because the context in which it is used is never the same. To illustrate the idea let us consider the word water which represents the water we drink, wash with, cook with, swim in, and that falls as rain, melts from snow, constitutes rivers, lakes, ponds and oceans, *etc*. The meaning of water in each of these contexts is slightly different but there is a common thread and hence the claim that the word "water" acts as a strange attractor for a diverse set of contexts involving water.

A language is an organization of a set of symbols whose semantics and syntax is a form of information. A similar claim can be made for a culture which Geertz [26] defined as "an historically transmitted pattern of meanings embodied in symbols, a system of inherited conceptions expressed in symbolic forms by means of which men communicate, perpetuate and develop their knowledge about and attitudes towards life." He goes on to add, that "culture is patterns for behavior not patterns of behavior".

Information as a form of organization for either language or culture, although it is symbolic like Shannon information, still cannot be associated with Shannon information because linguistic and cultural information is context dependent and meaningful. It is also the case that language and culture are like living organisms in that they evolve in ways that cannot be predicted. We may therefore use the same core argument we did in POE to rule out the description of language and culture and their

evolution with Shannon information. "The ensemble of possibilities and their entropy [for language and/or culture] cannot be calculated [1]". Therefore a definition of information as reducing uncertainty does not make sense since no matter how much one learns from the information in a linguistic or cultural system, as was the case with a biotic system, the uncertainty remains infinite because the number of possibilities of what can evolve is infinitely non-denumerable. Because science, technology, economics and governance are part of culture and it is also true that their evolution cannot be predicted; the argument we just made for language and culture applies to these subsets of culture as well.

At this point it is perhaps useful to define two forms of information micro-information consisting of isolated bits of information, the kind that are transmitted as Shannon information and are also components of a larger information system or organization and macro-information or the organization of a system like a living organism, a language, or a culture. Other forms of macro-information include the specific elements of a culture such as a business, an economic system, a polity, science and the technosphere. Narrative is the organization of a text or an utterance and therefore may be regarded also as a form of macro-information. Micro information is the string of characters and symbols that make up the narrative of a book, an article or a story.

There is still another property that the organizational information of language and culture share with living organisms that distinguishes them from Shannon information. This is the fact that language and culture, like life, are self-organizing phenomena and hence as is the case for biotic information and not the case for Shannon information we have a primitive model for the emergence of this information. Although we do not have a precise theory for how language and culture and the information and organization associated with them emerged we do have a number of proposals and models for how this might have happened through self-organization. Logan [21] contains a review of these models.

The notion of organization as a form of information is based on the notion that the systems we have reviewed consist of components that are organized by some organizing principle. For living systems the components are the biomolecules of which living organisms are composed and the constraints or instructional information that allows the conversion of free energy into work is the organizing principle of these biomolecules, which is propagated as the organism replicates.

This model holds for languages where grammar is the organizing principle and the components are the individual words or semantics. Replication takes place as children learn the language of their parents or care givers.

The model also holds for social systems where the culture as patterns for behavior is the organizing principle and the components are the behaviors and judgments of the individual's of the society. Replication occurs as young people learn the intricacies of their culture from a variety of sources including parents, teachers and peers.

For technology the technosphere is the organization and the components are the individual inventions or artifacts. Replication takes place each time an inventor or innovator makes use of components of the technosphere to create a new artifact or invention.

The model holds for economic-governance systems where the economic model is the organization and the components are the individual business transactions. Examples of different economic models based on the work of Johnson and Earle [27] are:

• Individual families as basic economic unit;

• The big man tribal economic unit where the big man is the coordinator of economic activity and serves at the pleasure of the people;
• The chief dominated tribal economic unit where the chief controls all the means of economic activity but answers to a tribal council;
• The state or manor economy where the monarch or the lord of the manor is the absolute ruler; as was case with Medieval manor system, Czarist Russia and France before the revolution;
• The market driven system which is democratic as in a republic like the USA or constitutional monarchy like the UK;
• The socialist state where private enterprise is controlled; and
• The communist state, which is state capitalism as was case with Soviet Union and Maoist China. China is now evolving into a mixed communist-socialist state.

The replication of economic-governance systems is through cultural and legal systems.

The model holds for science where the scientific method is the organizing principle and the components are the individual scientific theories. Replication occurs through the publication of scientific results and the education of new scientists.

16. Conclusions

We have demonstrated the relativity of information by showing that information is not a unitary concept independent of the phenomena it is describing or the frame of reference with respect to which it is defined. In particular we have shown that Shannon information cannot properly describe living organisms, language, culture and the various components of culture such as technology, science, economics and governance. We have examined the relationship of information to materiality, meaning and organization and showed that Shannon information is independent of meaning, organization and its material instantiation, which is just the opposite for biotic information, and the information associated with language and culture. We have also shown that that there exists an intimate relationship between information and organization for biotic systems and the elements of human culture including language, technology, science, economics and governance.

Acknowledgement

This paper draws heavily on two sources other than my earlier work, namely the paper Propagating Organization: An Enquiry [1] and the book *How We Became Posthuman* [6]. In a certain sense this paper is a remix of these two sources with help from the references cited below.

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