The Relativity of Information and Its Relationship to Materiality, Meaning and Organization

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Abstract

We examine the complex nature of information describing its historic development. We show that there is more than one concept of information and that information is a tool that comes in different versions depending on the phenomenon it is describing. We examine the relationship of information to materiality, meaning and organization. We show that Shannon information is independent of meaning, organization and its material instantiation, which is just the opposite for biotic information. We also show that that there exists a parallel between the information and organization of biotic systems and the elements of human culture including language, technology, science economics and governance.

> 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 (1948)
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> Information is a distinction that makes a difference – MacKay (1969)
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> Information is a difference that makes a difference – Bateson (1973)
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> 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 & Shmulevich (2007)

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, Blackberries and iPhones we are blanketed in information—drowning in information according to some. The irony of our total immersion in information 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. 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.

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, to MacKay's critique of Shannon information, to Bateson's formulation of information as the difference that makes a difference to the inclusion of information in biotic systems.

We will then attempt to answer the questions we have formulated above. First we review the work of Kauffman et al. (2007) that demonstrated that Shannon information cannot describe the information contained in a living organism. 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 also find a similar pattern of the link between information and organization in the various elements of human culture including language, technology, science, economics and governance.

Before beginning this analysis I wish to acknowledge that the impetus for this analysis emerged from my collaboration with Kauffman et al. (2007) and a close reading of Katherine Hayles (1999a) book *How We Became Posthuman*.

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. & 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 does 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 mathematization 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]. (Fisher 1925).

Another OED entry citing the early work of mathematizing information is that of R. V. L. Hartley (1928, p. 540) ”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.

Despite the early work of Fisher and Hartley cited above the beginning of the modern theoretical study of information is attributed to Claude Shannon (1948), 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 0s and 1s or in terms of some alpha-numeric code. Shannon (1948, pp. 392-94) 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.

According to Claude Shannon 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 information. So it is possible to have information without meaning, whatever that means.

MacKay's Counter Revolution: Where is the Meaning in Shannon Information?

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 (1951) 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 Weiner'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 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 (Hayles 1999b, p. 74). The notion of information independent of its meaning or context is like looking at a figure isolated from it ground. As the ground changes so too does the meaning of the figure.

Shannon whose position eventually prevailed defined information as the pattern or the signal and not 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 (ibid., p. 74)." He acknowledged that his definition of information was quite independent of meaning, however, although 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. (Shannon 1948)

I admire Shannon's frankness about his definition of information, which he devised to handle the engineering problems he faced. What I find extraordinary is that his definition limited in scope by his own admission became the standard by which all forms of information were gauged. There have been some slight variations of Shannon information like Kolomogorov information used to measure the shortest string of 0s and 1s 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 defended his definition from the attack that it was subjective because it defined information in terms of its effect on the receiver's thinking.

> 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 (Hayles 1999a, pp. 54-55).

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.

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 (1973) 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 he might actually have been influenced by MacKay (1969) 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.

Information in Biotic Systems

We have seen that as early as 1925 the notion of information as an abstraction was first introduced by Fisher (1925) and formalized by Shannon (1948) in 1948. 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 & 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 mathematization of information as was done by Fisher and Shannon but rather information was thought of as something capable of being transferred or communicated to or through a living organism or stored in a living organism in the form of DNA.

Life as Propagating Organization

Stuart Kauffman (2000) 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 (2007) 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 (1948) 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 (Kauffman et al.)." 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.

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 (ibid.).

In POE 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 (ibid.).

In POE 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 (ibid.).

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 that 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.

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 (2000) 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 the universal notion of information. After all Shannon formulated 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.

The Relativity of Information

Robert M. Losee (1997) 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 a contemporary IT expert or philosopher 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. 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 first surprise, namely the relativity of information. Information is not an invariant like the speed of light, which does not depend on its frame of reference or context.

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. Kolomogorov (Shiryayev 1993) 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 Kolomogorov 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 Kolomogorov information was intended to measure information content as the complexity of an algorithm on a Turing Machine. Shannon and Kologomorov 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

(1968). He "wanted to define information so that its meaning varied with context… [and] pointed out that whereas Shannon and Weiner define information in terms of what it is, MacKay defines it in terms of what it does (Hayles 1999a, p. 56)." Shannon-Weiner information is a noun or a thing and MacKay 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.

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 (2000) 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.

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 (1999a & b). 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 (Hayles 1999a, p. 18)."

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 (1999a) traces the origin of information theory to cyberneticians like Weiner, 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. 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 (2006 & 2007a)?

While it is true that the notion of information as used by the cyberneticians like Weiner, 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 slightly different from each other. The notion of information as the master or controller of the material world is more easily attributed to the cyberneticians than the communications engineers. 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.

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 (ibid.)." 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 Weiner that human intelligence and the human mind can some how 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 can slide from one medium or technology to another and not really change, McLuhan's "the medium is the message" aside because it is symbolic. 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 can alter the outcome.

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 Weiner (1948)

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. – Hayles (1999a, p. 18)

Shannon information cannot be nor was not it meant to be naively applied to complete biological systems, 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. 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 Kolomogorov information for biotic systems. Kolomogorov information, 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 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." 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 Kolomogorov information 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. 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 Kolomogorov 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 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 information is always associated with meaning, which is not necessarily the case with Shannon or Kolomogorov information. In the biotic frame information cannot be separated from the medium of its instantiation as is the case in the Shannon and Kolomogorov 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 God is

disembodied information, information without context where everything is explained in terms of the transfer of information, and some times it is information without meaning.

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 (1999a, p. 11) 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

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 (Hayles 1999a, p. 29)".

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 (Logan 2007b). The information that langauge and culture represent like biotic information is not Shannon or selective information but rather infromation 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 0s and 1s.

Let me provide an examples of how linguistic meaning depends on context based on my experience of have sired 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 by children had children and I became grandpa Dad became the father of my grandchildren.

Another example is the use of the term democracy. Democracy in North America and Europe has one meaning and in the Middle East another. Democracy is trumped by religion in a theocracy. If religion is not separated from a democratic state it will take over and destroy the democracy as happened in Iran. There has even been an alarming erosion of democracy and freedom in America under Bush and Cheney, which can in part be attributed to the influence of the religious right.

Enough said—I am drifting away from my topic—the point is that the meaning of words are context dependent. This is why when I (Logan 2006 & 2007a) identified words as representing concepts associated with a set of percepts that I also asserted that a word acts as a strange attractor for those percepts. 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., 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 (1973, p. 8) 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 (Kauffman et al. 2007).” 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 thee 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 systems 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 a uttereance 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 organzational 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 phenonena and hence as is the case for biotic information and not the case for Shannon information we have a primitive model for the emeregnce 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 (2007a) contains a review of these models.

The notion of organization as a form of information is based on the notion that systms 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 behaviour is the organization and the components are the behaviours 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 (1987) are:

• individual families as basic economic unit;
• the big man tribal economic unit where the big man is the co-ordinator 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 culture and legal systems.

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

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 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.

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