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Review

The Teleodynamics of Language, Culture, Technology and Science (LCT&S)

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Abstract: Logan [1] in his book The Extended Mind developed the hypothesis that language, culture, technology and science can be treated as organisms that evolve and reproduce themselves. This idea is extended by making use of the notion of teleodynamics that Deacon [2] introduced and developed in his book *Incomplete Nature* to explain the nature of life, sentience, mind and a self that acts in its own interest. It is suggested that language, culture, technology and science (LCT&S) like living organisms also act in their own self-interest, are self-correcting and are to a certain degree autonomous even though they are obligate symbionts with their human hosts. Specifically, it will be argued that LCT&S are essentially teleodynamic systems, which Deacon defines as "self-creating, self-maintaining, self-reproducing, individuated systems [2] (p. 325)".

Keywords: language; culture; technology; science; teleodynamics; morphodynamics; thermodynamics; organism; obligate symbiont

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1. Introduction

Although [teleodynamics] is the distinguishing characteristic of living processes, it is not necessarily limited to the biological—Deacon.

Terrence Deacon [2] in his book, *Incomplete Nature: How Mind Emerged from Matter* attempts to develop a scientific theory of how properties such as information, value, purpose, meaning, and end-directed behavior emerged from physics and chemistry. Deacon has developed a model to "first understand life, then sentience, then the human mind" [2] (p. 466) by reframing causality in terms of constraints on physical matter and by introducing the notion of teleodynamics. He explores the

emergence of consciousness, and the relationship between evolution and semiosis. His book is an attempt to develop an alternative to dualism that is compatible with canonical scientific thinking.

Deacon introduces in *Incomplete Nature* three nested levels of the dynamics and the organization of matter, namely:

1. **Homeodynamics or thermodynamics**, the lack of organization or the dynamics by which matter dissipates order or organization.

2. **Morphodynamics** by which self-organization can emerge as the result of the interactions of two homeodynamic or thermodynamic processes as is the case of the emergence of Bénard cells when a thin liquid is heated from one of its surfaces. Morphodynamics is not self-maintaining but eventually dissipates once the two thermodynamic processes have run their course. Once the temperature gradient at one of the surfaces of the thin liquid is removed the Bénard cells collapse and dissipate. To understand the origin of life Deacon considers two other examples of morphodynamics, namely the autocatalysis of organic chemicals suggested by Stuart Kauffman [3] and the self-assembly of the crystal like structures of cell membranes that combine teleodynamically.

3. **Teleodynamics** by which as the result of the interaction of two morphodynamic processes a system emerges that acts in its own self-interest. According to Deacon life emerges as a result of a higher-order reciprocal relationship or interaction between the self-organizing morphodynamic processes of autocatalysis and the self-assembly of the cell membrane that create a system, a living organism, with a sense of self that acts in its own self-interest. He also argues that sentience and mind also represent teleodynamic processes that emerge from the higher-order reciprocal relationship of morphodynamic processes, which in turn emerge from the higher-order reciprocal relationship of thermodynamic processes.

Morten Christiansen [4] has argued that human language can be considered as an organism that evolved to be easily learned. Terrence Deacon [5] in his book The Symbolic Species makes a similar argument. In my book *The Extended Mind: The Emergence of Language, the Human Mind and Culture* [1] I have argued that not only language, but also culture, technology and science can be considered as organisms that evolve and reproduce themselves. If we are to consider LCT&S as organisms then they must be able to act in their own interest as suggested by Deacon is the case of biological living organisms. I therefore would like to further extend my original notion that language, culture, technology and science (which will be denoted by LCT&S) behave themselves like living organisms and suggest that the teleological properties of agency, autonomy, acting in one's own interest and self-correction that Deacon [2] attributes to living organisms also applies to LCT&S.

We begin this project by first reviewing the arguments that LCT&S can be considered as organisms that are obligate symbionts with their human hosts. We then review Deacon's approach where he argues that origin and nature of life, sentience and mind can be understood in terms of teleodynamics. Then following the suggestion by Deacon [2] that teleodynamic systems are not necessarily biological, we then explore, to what extent LCT&S are teleodynamic in the sense that they are "self-creating, self-maintaining, self-reproducing, individuated systems [2] (p. 325)" as is the case with living organisms and the human mind.

2. Language as an Organism

Morten Christiansen [4] and co-workers Christiansen, Dale, Ellefson and Conway [6] developed the notion that language may be treated or represented as an organism. Christiansen developed this idea to suggest an alternative to Chomsky's [7] assertion that we are hard wired with a LAD (language acquisition device) that explains both Universal Grammar and how children are able to automatically learn their parents' language without any formal instruction. A number of other authors reached a similar conclusion that language evolves like an organism including Deacon [5], Batali [8], Kirby [9], Newport [10,11] and Elman [12,13]. The earliest and perhaps the purest expression of these ideas comes from Morten Christiansen's [4] notion of 'language as an organism, which he later elaborated with his co-workers:

> Language exists only because humans can learn, produce, and process them. Without humans there would be no language. It therefore makes sense to construe languages as organisms that have had to adapt themselves through natural selection to fit a particular ecological niche: the human brain. In order for languages to "survive", they must adapt to the properties of the human learning and processing mechanisms. This is not to say that having a language does not confer selective advantages onto humans. It seems clear that humans with superior language abilities are likely to have a selective advantage over other humans (and other organisms) with lesser communicative powers. This is an uncontroversial point, forming the basic premise of many of the adaptationist theories of language evolution. However, what is often not appreciated is that the selection forces working on language to fit humans are significantly stronger than the selection pressures on humans to be able to use language. In the case of the former, a language can only survive if it is learnable and processable by humans. On the other hand, adaptation toward language use is merely one out of many selective pressures working on humans (such as, for example, being able to avoid predators and find food). Whereas humans can survive without language, the opposite is not the case. Thus, language is more likely to have adapted itself to its human hosts than the other way around. Languages that are hard for humans to learn simply die out, or more likely, do not come into existence at all [6].
>
> More recently an alternative perspective is gaining ground, advocating a refocus in thinking about language evolution. Rather than concentrating on biological changes to accommodate language, this approach stresses the adaptation of linguistic structures to the biological substrate of the human brain. Languages are viewed as dynamic systems of communication, subject to selection pressures arising from limitations on human learning and processing [14].

The linguistic competence of each individual person represents an organism with its own unique semantics and syntax, which can communicate verbally only with members of the same language species. All those possessing an English organism can communicate with each other. The set of all English organisms form the English language species, which is generally referred to simply as the English language. The same is true for all the other human languages of the world. We regard the

English language facility of each individual as an organism. We regard the English language as the species of the individual English language organisms and consider all the individual language organisms as conspecifics.

The language possessed by each individual is in the words of Morten Christiansen "a kind of beneficial parasite—[an obligate] symbiont—that confers some selective advantage onto its human hosts without whom it cannot survive [14]". The language that belongs to the community, the linguistic species, as opposed to the language of individuals, evolves through the mutations that arise in the idiosyncratic use of the language by individuals that catch on. Those idiosyncratic mutations that catch on are incorporated into the individual language organisms of other individual members of the linguistic community or species.

Christiansen explains the universality of the characteristics of human language by simply applying natural selection to language and treating it as an organism which in order to survive had to evolve in such a way as "to fit the human learning and processing mechanism [4]".

Deacon [5] develops a position very similar to that of Christiansen,

> Children's minds need not innately embody language structures, if languages embody the predispositions of children's minds....We don't design language at all. It "designs" itself....Every effort to design a language has flopped.
>
> Languages are far more like living organisms than like mathematical proofs. The most basic principle guiding their design is not communicative utility but reproduction—theirs and ours. So, the proper tool for analyzing language structures may not be to discover how best to model them as axiomatic rule systems but rather to study them the way we study organism structure: in evolutionary terms. Languages are social and cultural entities that have evolved with respect to the forces of selection imposed by human users.

The language of the society as a whole is not an organism because it cannot reproduce itself but we can think of it as a species of organisms consisting of the languages of all the individuals of the society. De Saussure called the language of society "langue," and the language practiced by individuals "parole". With our definitions "langue" is the species and "parole" is an organism. Just as conspecifics of a biological species are able to reproduce among themselves the conspecifics of a linguistic species are able to communicate with each other verbally. English and French are linguistics species. The linguistic competence of each individual represents an organism with its own unique language, which can verbally communicate only with members of its linguistic species. Where the metaphor of species breaks down is that different language species can interbreed to create pidgin or creole languages which eventually can evolve into full fledge languages as was the case with the emergence of the many Latin-based languages of Europe such as Romanian, Italian, French, Catalan, Spanish and Portuguese.

3. Is Culture Also an Organism?

Geertz [15] defines culture 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." In *The Extended Mind* [1] I extended the "language is an organism" hypothesis of Christiansen [4] and Deacon [5] to culture, and then by extension to technology and science.

Because culture is essentially symbolic—a set of ideas, beliefs and knowledge, its acquisition by the human mind like that of language must be simple and straight forward if it is to be transmitted and hence survive. It is therefore logical to posit that culture like language evolved in such a way as to be easily acquired by humans. I therefore extended Christiansen's [4] idea that language is an organism to culture itself and suggested that culture is also an organism, an obligate symbiont [1]. If we accept this hypothesis then it follows by analogy that many of the conclusions Christiansen reached regarding language would apply to culture as well.

I have taken the liberty of transforming a paragraph of Christiansen, Dale, Ellefson and Conway [6] that I quoted above by replacing the word "language" with the word "***culture***" in bolded italics to arrive at some interesting thoughts about the nature of culture and its evolution. By making this substitution I have generalized and expanded Christiansen's [4] notion of "language as an organism" to the idea that culture can also be considered as an organism in the same metaphorical sense.

> ***Culture*** exists only because humans can learn, produce, and process them. Without humans there would be no ***culture***. It therefore makes sense to construe ***cultures*** as organisms that have had to adapt themselves through natural selection to fit a particular ecological niche: the human brain. In order for ***cultures*** to "survive", they must adapt to the properties of the human learning and processing mechanisms. This is not to say that having a ***culture*** does not confer selective advantages onto humans. It seems clear that humans with superior ***cultural*** abilities are likely to have a selective advantage over other humans... What is often not appreciated is that the selection forces working on ***culture*** to fit humans are significantly stronger than the selection pressures on humans to be able to use ***culture***. In the case of the former, a ***culture*** can only survive if it is learnable and processable by humans. On the other hand, adaptation toward ***culture*** use is merely one out of many selective pressures working on humans (such as, for example, being able to avoid predators and find food). Whereas humans can survive without ***culture***, the opposite is not the case. Thus, ***culture*** is more likely to have adapted itself to its human hosts than the other way around. ***Cultures*** that are hard for humans to learn simply die out, or more likely, do not come into existence at all.

Christiansen, Dale, Ellefson and Conway [6] quote has been altered by substituting the word *culture(s)* for *language(s).* We therefore conclude that culture like language can also be regarded as an organism that evolved to be easily acquired and preserved.

I further postulated that since culture, like language, evolved as an organism that was easy for the human mind to grasp that it gave rise to Universal Culture (UC) just as language evolved in such a way as to give rise to Universal Grammar (UG). It is the universality of human cognition that gives rise to UC and UG. The arguments for UG that Chomsky [7] developed are more or less accepted by the entire linguistic community although many do not accept his notion that we are hard wired with UG. The argument for UC on the other hand is less well known but just as compelling.

Lee Cronk [16] argues that the great diversity of cultures is perhaps an illusion because anthropologists are biased to look for differences rather than similarities. Languages also look very different from each other but they share a Universal Grammar according to Chomsky and most linguists. Cronk [16] suggests that maybe the same is true of culture. He cites Donald E. Brown's [17] book *Human Universals* and in particular the chapter titled "Universal People" which details:

> universals appearing in everything from the details of language and grammar to social arrangement to the ubiquity of music, dance, and play. The list includes some surprises. Every society has gossip, all societies understand the idea of a lie, they all have special types of speech for special occasions, they all use narrative, and they all have poetry with lines that take about three seconds to say. Men are everywhere on average more aggressive and likely to kill than women, though individual men and women do differ significantly from the average. Everyone has taboos on certain statements and certain foods. All societies are at least aware of dancing (though it is prohibited in some of them) and have some sort of music. Remarkably, everyone has children's music. If as cultural determinist dogma would have it, culture is all-diverse and all-powerful, why are there any such universals? Why aren't human cultures more diverse than they apparently are? Cronk [16].

4. The Culture of Each Individual in the Society Is an Organism

When we speak of culture as an organism we must decide if we are speaking of the culture of the whole society or of individuals within the society.

> People learn as individuals. Therefore, if culture is learned, its ultimate locus must be in individuals rather than in groups....If we accept this, then cultural theory must explain in what sense we can speak of culture as being shared or as the property of groups...and what the processes are by which such sharing arises [18].

Based on this insight of Goodenough we will assume that the culture of each individual of that group is an organism and that the culture of the society as a whole is a species composed of the culture organisms of each member of the society who are therefore conspecifics.

The culture of each individual in a society can be quite different because there are components of that individual culture that depend on the family they are members of, the locale and country in which they live, their profession, the company or organization for which they work, their religious beliefs, their hobbies and a large number of other factors.

5. The Reproduction of the Language Organism and the Culture Organism

If language and culture of individuals are to be considered as organisms then they must have the capacity to reproduce themselves. Stuart Kauffman's notion of the reproduction of living organisms by autocatalysis can be applied to language and culture of individuals operating as organisms. "A living organism is a system of chemicals that has the capacity to catalyze its own reproduction [3]". Let us use Kauffman's definition and apply it in a generalized form to language and culture operating as organisms.

We are justified to regard language and culture as living organisms because they are in the case of language a system of words and grammatical structures and in the case of culture symbols that have the capacity to catalyze their own reproduction. If we consider each person's individual use of language or culture as an organism then we may regard language or culture reproducing itself each time a child acquires his or her parents' language and culture. With this definition we not only meet Kauffman's criteria that an organism catalyzes its own reproduction but we are able to consider the evolution of these organisms using Darwin's [19] simple one line definition of evolution, namely, "descent with modification." For Darwin descent meant reproduction. By considering the language or culture of each individual in the society as an organism we can speak of a language reproducing itself. In this case the inheritance or descent is not by diploidy but the polyploidy of parents, siblings, peers, teachers, relatives and society in general. One can now apply the concept of natural selection to the language or culture organism of each individual in a society.

I have in an earlier study The Sixth Language Logan [20] demonstrated that speech is part of an evolutionary chain of languages which also includes writing, mathematics, science, computing and the Internet. Each of these languages acts as a cultural replicator that propagates its organization through their memes. Like biological organisms they are living cultural entities that evolve, compete and pass on some form of information. The same can be said of culture itself; it is a living organism. The argument can be extended to include technology, which is an integral part of culture. Science as both a cultural artifact and a language qualifies on both these accounts to be regarded as an organism.

It has also been noted in Kauffman, Logan *et al.* 2007 [21] that language and culture, like living organisms, also propagate their organization and hence their information. This also includes science and technology, which are part of culture but which I treat separately because they provide vivid examples of propagating organization and teleodynamic organization. The information that language and culture represent like biotic information is not Shannon [22] or selective information but rather information with meaning, namely MacKay [23] structural information.

Language and culture are like living organisms in that they evolve in ways that cannot be predicted. 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 [24].

6. Memes and the Evolution of Language, Culture, Technology and Science

Richard Dawkins [25] in his book The Selfish Gene introduced the notion of the meme, analogous to the gene, that serves as the mechanism by which an idea, a behaviour, a fashion style, a word, a grammatical construction, a cultural idea, a technological idea, or a scientific paradigm can be transmitted from one mind to another. Dawkins and his supporters suggest that memes like genes, undergo Darwinian descent, modification and selection and hence evolve in a manner similar to living organisms. Descent occurs through imitation and modification through the imitator of the meme putting their particular spin on the meme due to the uniqueness of their life experience.

The evolution of technology follows a pattern similar to that of living organisms as has been pointed out by a wide variety of authors. The first was the English critic and satirist Samuel Butler writing a mere four years after the publication of *The Origin of the Species*. More recent and more serious suggestions have been made by Basalla [26], Cziko [27] Mokyr [28], Vincenti [29] and Levinson [30].

Basalla [26] cites three basic analogies between technological and biological evolution. The first is the fact of the great variety of both biological organisms and technological tools. Basalla cites the fact that the U.S. Patent Office granted approximately 4.7 million patents between 1790 and 1988, the date of the publication of his book *The Evolution of Technology*. As he put it: "The variety of made things is every bit as astonishing as that of living things."

Basalla's second point is that technology evolves through a process of descent and modification: "Any new thing that appears in the made world is based on some object already in existence [26]". He cites many examples of how innovative technologies borrowed significantly from earlier technologies citing the cotton gin, the electric motor and the transistor as three examples.

The third point that Basalla makes is that technologies survive through a selection process by which a society chooses a particular technology from a large number of variations for incorporation into its material life.

Mokyr's [28] approach to the evolution of technology is to consider the evolution of know-how rather than the physical artifacts:

> The approach I adopt here is that techniques…, namely, the knowledge of how to produce a good or service in a specific way—are analogues of species, and that changes in them have an evolutionary character. The idea or conceptualization of how to produce a commodity may be thought of as the genotype, whereas the actual technique utilized by the firm in producing the commodity may be thought of as the phenotype of the member of a species. The phenotype of every organism is determined in part by its genotype, but environment plays a role as well. Similarly, the idea constrains the forms a technique can take, but adaptability and adjustment to circumstances help determine its exact shape. Invention, the emergence of a new technique, is thus equivalent to speciation, the emergence of a new species.

Vincenti's [29] approach to the evolution of technology was to develop a "variation-selection model for the growth of engineering knowledge." He suggests that the most efficient way to design new technology is to create variations vicariously and cheaply through modeling (either physical models or computer simulations) and then employ a selection process to pick the form of technology that will be finally built. Vincenti's focus like that of Mokyr is on know-how and also the most efficient way of achieving it through vicarious variation and selection.

Cziko [27], who cites the work of Basalla [26], Mokyr [28] and Vincenti [29], has created a Universal Selection Theory that includes the notion that technologies evolve in a manner similar to living organisms. "The adapted nature of technology and its progress is hard… to doubt."

Levinson [30] in The Soft Edge introduces the principle of anthropotropism whereby not only do technologies evolve but they evolve in such a way that they replicate human characteristics and

behaviours and actually adapt to them. This principle incorporates McLuhan's notion that technologies and media are extensions of our bodies and psyches.

Finally, I cite my own work in which I too saw the evolution of technology as analogous to that of living organisms:

> Cognitive tools and physical technology are two resources at the disposal of human innovators, and the needs or demands of society are often the motivating force. Necessity is the mother of invention, yet invention does not occur in a vacuum. All of the previous innovations in a culture provide the resources, both cognitive and physical, for the next level of innovation. The previous innovations also contribute to changes within the socioeconomic system that give rise to new social demands. Each new invention, technological innovation, or discovery gives rise to new technical capabilities, new cognitive abilities, and new social conditions. These then interact with the existing economic, political, social, cultural, technical, and cognitive realities of the culture to set the stage for the next round of innovation. Thus, technological change in our model is part of an ongoing iterative process. It began with the inception of Homo sapiens and continues to this day at an ever-quickening pace [20].

Science is another symbol-based activity unique to humans, which also propagates its organization and evolves like a living organism. The mechanism for the propagation of science's organization is what Thomas Kuhn [31] termed normal science. Every success in science gives rise to a paradigm, which is articulated and applied to as many phenomena as possible. This is the mechanism of descent. Once a paradigm fails to provide a satisfactory description of nature a period of revolutionary science begins with the search for a new paradigm. This is the mechanism of modification. If the new paradigm provides a satisfactory explanation to the science community by providing replicable results a new round of normal science begins. This is the mechanism of selection. Science propagates its organization through normal science and evolves by descent, modification and selection just like living organisms. The analogy between the Darwinian evolution of living organisms and the process of descent, modification and selection in Kuhn's model led him to cautiously conclude at the end of his analysis of scientific revolutions the following:

> The analogy that relates the evolution of organisms to the evolution of scientific ideas can easily be pushed too far. But with respect to the issues of this closing section it is very nearly perfect… Successive stages in that developmental process are marked by an increase in articulation and specialization. And the entire process may have occurred, as we now suppose biological evolution did, without benefit of a set goal, a permanent fixed scientific truth, of which each stage in the development of scientific knowledge is a better exemplar [31].

Karl Popper [32] whose description of science differs from that of Kuhn's [31], nevertheless also found an analogy between the evolution of science and that of living organisms:

> The growth of our knowledge is the result of a process closely resembling what Darwin called "natural selection"; that is, the natural selection of hypotheses: our knowledge consists, at every moment, of those hypotheses which have shown their

> (comparative) fitness by surviving so far in their struggle for existence; a competitive struggle which eliminates those hypotheses which are unfit.

McLuhan [33] has pointed out that a figure changes if it is introduced into a different ground. If one considers a meme as a figure then when it is transferred from one human to another there is bound to be a change of ground, which could result in a modification of the meme. As for selection some memes are more easily imitated than others and hence more likely to survive. It can also be the case that some memes increase the survival rate of their users and hence they have a selection advantage. While some controversy exists regarding whether memes are a valid scientific concept, I believe that they are a useful metaphor that sheds light on the way in which language, culture, technology and science evolve. Certainly the idea of a meme is a meme in itself, which has been copied or imitated from the original idea/meme of Dawkins [25] by many prominent scholars. I would therefore be so bold as to suggest that the meme self-organized itself, self-created itself and has self-maintained itself teleodynamically as described by Deacon, which forms the focus of the remainder of this paper.

7. Terrence Deacon's Incomplete Nature

Terrence Deacon [2] in his book *Incomplete Nature: How Mind Emerged from Matter* attempts to "first understand life, then sentience, then the human mind [2] (p. 466)" in terms of what he calls absentials, which he defines in terms of the constraints on physical matter as is described below. He also attempts to deal with issues such as values, purpose, meaning, from a scientific perspective as well as find an alternative to dualism that is compatible with canonical scientific thinking.

The book contains the paradox that something that is absent, in fact, gives rise to the most critical things for human existence, namely life and mind. Deacon formulates in scientific terms, making use of the concepts of thermodynamics, morphodynamics and teleodynamics, an explanation of what so many of us have known intuitively that life, sentience and higher order human mental processes cannot be explained in terms of computations and cybernetic processes nor can biology be derived from reduced to or predicted from physics. "Computations and cybernetic processes are insentient because they are not teleodynamic in their organization [2] (p. 536)." Deacon's emergent approach builds on and extends Maturana and Varela's [34] notion of autopoiesis and Stuart Kauffman's [3,35] idea of autocatalysis.

Deacon introduces and makes use of a number of special terms, including morphodynamics, and teleodynamics. As I plan to extend Deacon's approach to provide insights into the nature of language, culture, technology and science we need to define these two terms. Morphodynamics has current currency but Deacon uses it in a special way and hence it needs clarification as to how he uses it. Teleodynamics is a neologism that he has coined so we will need to define it in the way that Deacon uses it.

8. Morphodynamics

The standard definition of morphodynamics is "of or pertaining to dynamic changes in morphology [36]". Deacon uses the term in a special way to connote the process of self-organization as is the case in which Bénard cells form or self-organize when a thin liquid layer is constantly heated

from above or cooled from below. Deacon [2] points out, as has Kauffman [3], that life depends of extracting energy from the environment and by making use of constraints that are built up "by morphodynamic action" [2] to use that energy to create the work needed for metabolism and reproductions.

Life therefore depends on the construction of constraints by morphodynamics or self-organization as is described by Deacon.

> Evidence that life involves morphodynamic processes comes from two attributes that are characteristic of all organisms. First, organisms are incessantly engaged in processes of creating and maintaining order. Their chemical processes and physical structures are organized so that they generate and maintain themselves by continually producing new appropriately structured and appropriately fitted molecular structures. Second, to accomplish this incessant order generation, they require a nearly constant throughput of energy and materials. They are in this respect dissipative systems. Together, these two characteristics give life its distinctive capacity to persistently and successfully work against the ubiquitous, relentless, incessantly degrading tendency of the second law of thermodynamics. Individual organisms do this via metabolism, development, repair, and immune response [2] (p. 265).

Morphodynamic processes unlike thermodynamic processes, which dissipate or randomize order, actually create order, as is the case with Bénard cells. Deacon argues that biological systems rely on a special form of interdependency between complementary morphodynamic processes in order to generate their constraints internally (see Teleodynamics below). To exemplify this he develops a simple and empirically testable molecular model involving two morphodynamic processes, which are ubiquitously present in all organisms, namely the self-assembly of cellular membranes and the autocatalysis of organic compounds so essential to life and its ability to reproduce itself.

LCT&S in analogy with life have a morphodyamics in the sense that they operate within a set of structural forms that constrain their behaviour. For language grammar acts as their morphodynamic constraint. For culture cultural norms and values act as their morphodynamic constraint. For technology the laws of nature's grammar act as their morphodynamic constraint. For science the scientific method acts as their morphodynamic constraint.

9. Teleodynamics

One of the key new ideas that Deacon introduces in *Incomplete Nature* is the notion of teleodynamics, which is essentially the key property that defines a living organism or a self that acts in its own self-interest.

> Even organisms as simple as bacteria have properties that qualify them as selves …. Issues of teleology, agency, representation, and value are critical elements of self that need to be considered …. [Teleodynamics is] the core property which links the selves of even the simplest life forms with that seeming ineffable property that characterizes the human experience of self [2] (466 & 468).

> Because organisms are teleodynamic systems, they do not merely react mechanically and thermodynamically to perturbation, but generally are organized to initiate a change in their internal deficits [2] (p. 487).

An organism has choice. Its reaction to external stimuli is based on what is best for it. Non-living things have no choice, the best they can do is self-organize as is the case with crystal formation or the phenomenon of the Bénard cell.

> Teleodynamics was defined as a dynamical organization that exists because of the consequences of its continuance, and therefore can be described as being self-generating over time. But now consider what it would mean for a teleodynamic process to include within itself a representation of its own dynamical final causal tendencies …. The whole produces the parts and the parts produce the whole. But then a teleological process in which one critical dynamical component is a representational process that interprets its own teleodynamic tendency extends this convoluted causal circularity one level further [2] (p. 526).

As Deacon points out morphodynamics or self-organization does not create a self, *i.e.*, an individual that acts in its own interest. This requires a third level of dynamics, teleodynamics, which depends on morphodynamics. "Teleodynamics can be understood as characterizing the distinguishing dynamics of life" [2] (p. 275).

> The dependence of teleodynamic on morphodynamics and morphodynamics on thermodynamics constitutes a three-stage nested hierarchy of modes of dynamics, which ultimately links the most basic orthograde process—the second law of thermodynamics—with the teleodynamic logic of living and mental processes [2] (p. 276).

> The core hypothesis of this book is that all teleodynamic phenomena necessarily depend upon, and emerge from, simpler morphodynamic and homeodynamic (*i.e.*, thermodynamic) processes [2] (p. 487).

Deacon suggests that the interdependent combination of two morphodynamic processes, namely that of autocatalysis and the crystal like "self-assembly" such as produces viral shells or cell membranes, can produce a simple form of molecular teleodynamics. Because of its simplicity he suggests that this may even be a potential mechanism for how life might have emerged. Deacon claims that autocatalysis by itself cannot give rise to a living entity because while it is self-promoting it is not self-regulating or self-preserving [2] (p. 295). A second feature is required, namely, self-containment. The self-organization of organic chemical structures that form the cell's membrane and provide containment is similar to the way crystals form. "Containment creates physical individuality and is a necessary step for the creation of a "self", a living self, that can act teleologically in its own self-interest [2] (p. 296)."

The trick is how to get these two morphodynamic processes, autocatalysis and membrane construction to co-emerge. They in fact form a reciprocal support for each other because both autocatalysis and the self-assembly of cell membranes are by themselves "self-undermining and self-limiting" [2] (p. 308) as they are self-depleting processes. Deacon's solution to this problem is his

suggestion that, these intrinsic limitations of autocatalysis and self-assembly processes are also a source of potential synergy. The conditions produced by each of these processes and their limitations together comprise a complementary and reciprocally supportive effect.

> The reciprocal complementarity of these self-organizing processes means that spontaneous linkage of autocatalysis with self-assembly containment is a possibility [that] creates the potential for self-repair, self-reconstitution, and even self-replication in a minimal form [2] (pp. 304–306).

Teleodynamics is the essential ingredient that creates a living organism, a self that propagates its organization.

> The self-referential convolution of teleodynamics is the source of a special emergent form of self that not only continually creates its self-similarity and continuity, but also does so with respect to its alternative virtual forms. Thus autonomy and agency, and their implicit teleology, and even the locus of subjectivity, can be given a concrete account. Paradoxically, however, by filling in the physical dynamics of this account, we end up with a non-material conception of organism and neurological self, and by extension, of subjective self as well, a self that is embodied by dynamical constraints. But constraints are the present signature of what is absent. So surprisingly, this view of self shows it to be as non-material as Descartes might have imagined, and yet physical, extended, and relevant to the causal scheme of things as is the hole at the hub of the wheel [2] (p. 484)".

10. Are Language, Culture, Technology and Science Teleodynamic Phenomena?: A Probe

The probe that I would like to examine is whether or not Deacon's notion of teleodynamics applies to language, culture, technology and science (LCT&S). If LCT&S behave as organisms as I have suggested then perhaps some form of teleodynamics might pertain to their organization and their persistence. I must confess that the motivation for this probe and the reason I embarked on this project to explore the question: "Are language, culture, technology and science teleodynamic phenomena?", came from the following passage from Deacon's [2] book, *Incomplete Nature*.

> Teleodynamics can be understood as characterizing the distinguishing dynamics of life. However, rather than being an abstract description of the properties that living processes exhibit, it is a specific dynamical form that can be described in quasi-mechanical terms. Although it is the distinguishing characteristic of living processes, it is not necessarily limited to the biological. Teleodynamic processes can be identified with respect to the specific end-directed attractor dynamics they develop toward [2] (p. 275).

This passage prompted the following thoughts:

Do language, culture, technology and science (LCT&S) represent teleodynamic processes? Is there not an autonomy of LCT&S as they maintain themselves, as they self-organize, as they have agency?

They are obligate symbionts and hence their energy is provided by their hosts, but they assist their hosts to acquire energy and do work.

With regard to autonomy—the LCT&S do not have energy autonomy in the sense that they depend on humans for their source of energy, but they are autonomous from the standpoint of their development in that a single individual cannot destroy them as they are self-contained. An individual can contribute to their evolution and enrichment by creating a neologism that catches on, or a new cultural pattern like the Beau Brummel suit jacket, or a technological invention or innovation like all of Steve Jobs' Apple products or a new scientific paradigm like Einstein's theory of relativity for LCT&S respectively.

It seems to me that language, culture, technology and science each have end-directed attractor dynamics they develop toward. This is why I think LCT&S represent teleodynamic processes. I believe that they are in fact autonomous agents that maintain themselves, self-organize, and seem to have agency.

The following description of Deacon of the processes of living organisms seems to apply with almost equal validity to LCT&S.

> We find processes [for both living organisms and LCT&S] that (a) consistently partition thermodynamic processes so that many components processes follow trajectories that run radically counter to global thermodynamic probabilities; (b) are highly heterogeneous in structure and dynamics; (c) produce processes/behaviors that are so convoluted, divergent, and idiosyncratic as to defy compact algorithmic description; (d) generate and maintain aggregate systemic properties that are quite distinct from any properties of the components, and (e) reflect the effects of deep historical contingencies that may no longer be existent in their present context [2] (p. 267) {with my addition of the words in the square bracket to indicate that LCT&S behave like living organisms}".

Language, culture, technology and science (LCT&S) (a) do not "run radically counter to global thermodynamic probabilities" but they are the tools that enhance their human host's ability to do so. There is no question that like living organisms (b) LCT&S "are heterogeneous in structure and dynamics" and that (c) they "defy a compact algorithmic description." It is also the case that LCT&S like living organisms certainly (d) have "systemic properties that are quite distinct from any properties of the[ir] components." Finally, LCT&S like living organisms are emergent phenomena and (e) "reflect the effects of deep historical contingencies that may no longer be existent in their present context."

Not only do LCT&S parallel the processes of living organisms they also undergo a parallel form of Darwinian evolution of descent, modification and selection. Deacon describes the evolution of living organisms in the following way, "the process of evolution, rather than merely maintaining and reproducing dynamical form, exhibits a spontaneous tendency for its dynamics to diversify and complexify these forms, both intrinsically and in their relationship to their contexts [2] (p. 275)". This description fits both living organisms and LCT&S.

"The incessant need [of living organisms] to replace and reconstruct organism components depends on synthetic form-generating processes, not merely resistance to breakdown [2] (p. 276)". LCT&S also

in a certain sense replace and reconstruct their components through form-generating processes (new words through grammaticalization, portmanteau or neologisms; new cultural practices through technological change, diffusion, acculturation; technological breakthroughs through invention, innovation and diffusion; and new scientific paradigms developed in what Kuhn terms revolutionary science respectively for LCT&S. Like living organisms LCT&S are also self-correcting and self-maintaining.

Reproduction of life is "the construction of a dynamical physical system, which is a replica of the system that constructed it, in both its structural and functional respects, though not necessarily a faithful replica in every detail [2] (p. 278)". This is also true of LCT&S. Each reproduces itself from generation to generation just like life. Furthermore a living organism not only must reproduce itself but it must reproduce its reproducibility. LCT&S each have this capacity to reproduce their reproducibility or else language, culture, technology and science would not survive from one generation to another.

Deacon notes that "life requires the constant acquisition of energy and raw materials from its environment, and an incessantly active, tightly orchestrated use of these to stay ahead of the ravages of thermodynamic decay [2] (p. 280)". LCT&S, on the other hand, acquire their energy from their hosts, as they are obligate symbionts that repay their hosts by increasing their host's ability to acquire energy and other resources that promote their well being.

Deacon also suggests that "teleodynamic systems [can be] found in ecosystems, complex organisms, brains, and even social systems [2] (p. 325)". I take this as support of my extension of Deacon's program to explicitly contend that language, culture, science and technology (LCT&S), which are social systems, are also teleodynamic systems that are "self-creating, self-maintaining, self-reproducing, individuated systems [2] (p. 325)".

11. To What Extent are Language, Culture, Technology and Science "Self-Creating, Self-Maintaining, Self-Reproducing, Individuated" and Teleodynamic Systems

The first thing that we must remember is that the terms language, culture, technology and science refer to both individual obligate symbiont organisms possessed by individual humans and the four respective species that these individual organisms belong to. In other words each individual possess an LCT&S organism but the sum of all the LCT&S individual organisms make up the respective species of language, culture, technology and science. For example, I possess as obligate symbionts the organisms of the English language I use to communicate, the Toronto Canada urban culture I am part of, the ability to use the technologies that are part of my life and the science activities I pursue, which allow me to communicate with other speakers on English, participate in the culture of my city and country, operate in the technosphere and participate in the science community that I operate within, respectively.

The claim that LCT&S are teleodynamic systems suggests that the properties of self-creation, self-maintenance and self-production belong to these four species, respectively. Language reproduces itself and came into being by self-organizing the signals used by individuals into a system of communication that could be easily learned and hence reproduced by imitation. This mechanism also insured the self-maintenance of the system as uses of expressions that did not maintain the integrity of the system would not be imitated and hence discarded. Culture followed a similar pattern. The cultural

practices that were easy to learn and insured the survival of the community in the environment in which they found themselves self-organized and self created the cultural species of the society. Practices that ran counter to norms of society and which were inconsistent with the demands of the environment quickly died out and hence the self-maintenance of culture. Technologies and tools that aided survival self-organized and survived, but those that did not aid survival of their host did not themselves survive. Science by its very nature is a self-maintaining activity as theories inconsistent with the observation of nature would be eventually detected and discarded.

12. The Three-Stage Development of the Teleodynamics of Life

Deacon built his model on teleodynamics processes that emerge from the higher-order reciprocal relationship of morphodynamic processes, which in turn emerge from the higher-order reciprocal relationship of thermodynamic processes. "So the dependence of teleodynamics on morphodynamics and morphodynamics on thermodynamics constitutes a three-stage nested hierarchy of modes of dynamics [2]. I would like to propose that a similar three-stage nested hierarchy of modes of dynamics have resulted in the emergence of the LCT&S species.

The trick in the emergence of living organisms and the teleodynamics that characterize them was how to get the two morphodynamic processes, autocatalysis and membrane construction to co-emerge. They in fact formed a reciprocal support for each other because both autocatalysis and the self-assembly of cell membranes are by themselves "self-undermining and self-limiting" [2], (p. 308) as they are self-depleting processes. Deacon's solution to this problem was his suggestion that, the intrinsic limitations of autocatalysis and self-assembly processes are also a source of potential synergy. The conditions produced by each of these processes and their limitations together comprise a complementary and reciprocally supportive effect. The emergence of the morphodynamic processes in turn required "a complementary and reciprocally supportive effect" of two thermodynamic processes. This is the essence of Deacon's three-stage nested hierarchy of modes of dynamics that he claims resulted in the emergence of life.

13. The Three-Stage Development of the Teleodynamics of LCT&S

If Deacon's notion that teleodynamics based on the three-stage nested hierarchy of modes of dynamics allows living organisms to be "self-creating, self-maintaining, self-reproducing, individuated systems [2] (p. 325)", applies to LCS&T then we should be able to identify a three-stage nested hierarchy of dynamic modes for the origin of language, culture, technology and science.

14. Emergence of Generative Verbal Language

Non-verbal vocalization and gesture together with intention "comprise a complementary and reciprocally supportive effect" leading to the mimetic communication of intention as defined by Merlin Donald [37].

Vocalization and communication of intention by mimetics "comprise a complementary and reciprocally supportive effect" leading to protolanguage.

Protolanguage and grammaticalization in turn "comprise a complementary and reciprocally supportive effect" leading to fully verbal language which is generative.

Generative verbal language and recorded tallies in turn "comprise a complementary and reciprocally supportive effect" leading to written language and numerical notation.

Verbal grammatical speech emerges from proto-language and proto-language emerges from mimetic communication. Mimetic communication is a non-verbal form of communication, which entails the use of hand signals, mime, gesture and prosodic vocalization. Donald [37] claimed was the cognitive laboratory in which verbal language developed. Mimesis according to Donald [38] "establishes the fundamentals of intentional expression in hominids, without which language would not have had an opportunity to evolve such a sophisticated, high-speed communication system as modern language unless there was already a simpler slower one in place."

Mimetic skill represented a new level of cultural development, because it led to a variety of important new social structures, including a collectively held model of the society itself. It provided a new vehicle for social control and coordination, as well as the cognitive underpinnings of pedagogical skill and cultural innovation. In the brain of the individual, mimesis was partly the product of a new system of self-representation and mostly the product of a supramodular mimetic controller in which self-action may be employed to 'model' perceptual event representations. Many of the cognitive features usually identified exclusively with language were already present in mimesis: for instance, intentional communication, recursion, and differentiation of reference.

"There is a vestigial mimetic culture embedded within our modern culture and a mimetic mind embedded within the overall architecture of the modern human mind [37] (p. 162)."

Donald [38] (p. 179) sees a direct connection between speech and manual articulation or hand signaling. He posits that mimetic skills and communication laid the foundation for human language also sees a strong connection between tool making and mimetics. "Tool making was probably the first instance of behavior that depended entirely upon the existence of self-cued mimetic skill."

Protolanguage, which Derek Bickerton [39] coined to describe a stage in the development of human language in which a lexicon of a small number of words existed without syntax and utterances were confined to less than five words.

Bickerton claims [39,40] that protolanguage in which the first words were used symbolically emerged with Homo erectus, which means the first bifurcation can be dated as far back as 2 million years ago. The second and third transitions, on the other hand, can be dated to the emergence of fully syntactilized language, which occurred only 50 to 100 thousand years ago and seems to be correlated with the explosion of human culture and technological progress of that time period [39].

Bickerton [41] (p. 209) suggests that protolanguage with its limited lexicon and lack of syntax, "arose directly from the requirements of group foraging, predator avoidance, and the instruction of the young, rather than from specifically social interactions between individuals (whether competitive or co-operative)… As soon as protolanguage had achieved a critical mass...it was undoubtedly co-opted for a variety of social purposes, which in turn contributed to its further expansion."

Grammaticalization is the process by which grammar emerges basically from the lexicon. It is the process whereby nouns that represent concrete objects and verbs that represent actions and relations among entities "become prepositions, auxiliaries, and other grammatical forms… Grammatical constructions and the concepts they represent become emancipated from the concrete and come to

express purely abstract notions, such as tense, case relations, definiteness, and so on. It is important to note, however, that the sources for grammar are concepts and words drawn from the most concrete and basic aspects of human experience [42] (pp. 145,152–153)."

The origins of speech and the human mind are shown to have emerged simultaneously as the bifurcation from percepts to concepts and a response to the chaos associated with the information overload that resulted from the increased complexity of hominid life. As our ancestors developed tool making, controlled fire, lived in larger social groups and engaged in large-scale co-ordinated hunting their brains could no longer cope with the richness of life solely on the basis of its perceptual sensorium and as a result a new level of order emerged in the form of conceptualization and speech. Speech arose simultaneously as a way to control information and as a medium for communication. Rather than regarding speech as vocalized thought one may just as well regard thought as silent speech.

The mechanism that allowed the transition from percept to concept was the emergence of speech. The words of spoken language are the actual medium or mechanism by which concepts are expressed or represented. Words are both metaphors and strange attractors uniting many perceptual experiences in terms of a single concept. Spoken language and abstract conceptual thinking emerged simultaneously as the bifurcation from non-verbal communication skills and the concrete percept-based thinking of pre-lingual hominids.

The transition from percept-based thinking to concept-based thinking represented a major discontinuity in human thought and entailed three major stages or breakthroughs in hominid cognition:

1. Manual praxic articulation (or tool making and use),
2. Social organization (or the language of social interaction), and
3. Preverbal communication, which entails the use of hand signals, mime, gesture and prosodic vocalization [1].

15. Emergence of Culture

As we have already noted the emergence of language and culture in genus Homo are closely linked. Culture has influenced the origin and development of language, but it is also true that language is an essential component of culture. Biological reproduction and altruism "comprise a complementary and reciprocally supportive effect" leading to the nuclear family, which emerged with the beginning of genus Homo even before the arrival of Homo sapiens.

The nuclear family and the benefits of the control of fire "comprise a complementary and reciprocally supportive effect" leading to protoculture of co-ordinated hunting and gathering,

Protoculture and verbal language "comprise a complementary and reciprocally supportive effect" leading to symbolic culture as defined above by Geertz [15] (p. 8), *i.e.*, "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." Durham [43] (pp. 8–9) also defines culture "as a system of symbolically encoded conceptual phenomena that are socially and historically transmitted within and between populations."

The three nested stages are the nuclear family, clans around the campfire, symbolic culture that emerges with language/and then bifurcates into oral culture, written culture, electric mass culture, and digital culture as new media emerge. The nuclear family remained a part of later forms of culture.

16. Emergence of Technology

As noted tool making, culture and language are all closely linked. Found objects and intention "comprise a complementary and reciprocally supportive effect" leading to tool making.

Tool making and verbal language "comprise a complementary and reciprocally supportive effect" leading to agriculture and complex tools and the systematic development of technology.

17. Emergence of Science

Trial and error observation of nature and verbal language "comprise a complementary and reciprocally supportive effect" leading to primitive science.

Primitive science and empirical method "comprise a complementary and reciprocally supportive effect" leading to modern science.

Verbal language provides the conceptual toolbox that allows the lessons formed from experiences and the observation of nature to be formulated systematically which is the essence of science. Science is basically a description of nature and in its earliest formulation was combined with myths and tales in an attempt to explore the forces of nature. It was only with empirical investigation and the adoption of the scientific method that modern science, which is self-regulating finally emerged during the Renaissance.

18. Creating and Maintaining Order

Another common link of living organisms and LCT&S is that they all create and maintain order within their respective domains. "Organisms are incessantly engaged in processes of creating and maintaining order [2] (p. 265)". The same is true of language, culture, technology and science. Language helps us to order our understanding of our needs and to plan our activities through the ability to conceptualize; culture helps us to order our social interactions; technology helps us to order our physical environment and science helps us to understand the environment in which we exist.

The "chemical processes and physical structures [of living organisms] are organized so that they generate and maintain themselves by continually producing new appropriately structured and appropriately fitted molecular structures [2] (p. 265)".

In a similar way the mental processes that are entailed in LCT&S are organized so that they generate and maintain themselves by continually producing new appropriately structured and appropriately fitted intellectual structures.

19. Self-Interest

If we are to establish our hypothesis that language, culture, technology and science (LCT&S) are teleodynamic phenomena like living organisms then we must show that they also act in their own self-interest.

Language acts in it own self-interest by evolving so that it is easy to learn. It also makes those that hear or see mistakes in the language feel uneasy and feel the need to correct the mistake. Parents correct children's mistakes even when the child is acting logically. For example, children have to be taught the exceptions to the rules of grammar especially in English where one says, many deer not many deers. I went there not I goed there. I fighted with him instead of I fought with him. I slept there not I sleeped there. Even spelling errors beginning with the printing press made our language organism uncomfortable. But then the language species can evolve and words, which were once unacceptable like orientate for orient become acceptable. There are also times when the culture organism over rules the language organism and kills the original meaning of the word "gay" and ironically the language organism of some individuals in the culture then use the word "gay" metonymically as a slur without any reference to homosexuality.

Cultures act in their own self-interest by inculcating that their ways of doing things are superior to other cultures which are designated with such pejoratives as: barbarian, savage, alien, foreign, gentile, gringo, or the natives. It is a universal among the cultures of the world that those of other cultures were referred to in a pejorative manner. A culture will demand of its inhabitants that they sacrifice themselves for the sake of the preservation of their culture. Those that fight in wars are said to fight for king and country in the UK or for the Fatherland in Germany or the Patria in Italy or for the flag and country in the USA. The culture species acts in its own self-interest sometimes at the expense of the individuals that are part of that culture.

Technology acts in its own self-interest by demanding that new forms perform more effectively or efficiently. The demand for empirical evidence of whether or not a tool is effective is the mechanism by which technology acts in its own self-interest. If a tool works it becomes a meme and evolves and hybridizes with other tools. Another condition that technology demands of each new innovation is that it works compatibly with the existing technological infrastructure. Tools are extensions of their users and their hosts [33].

Science acts in its own self-interest when it demands that all statements made in its name be falsifiable and when it demands that experimental results be replicated independently.

In describing the teleological nature of living things and the role of autocatalysis Deacon and Cashman [44] state, "It [*i.e.*, purpose/final cause] is a general consequence that has a beneficiary… A final cause is that for the sake of which something is generated. So what is the beneficiary of autocatalysis?" We might ask the same question, what is the beneficiary of LCT&S. There are two classes of beneficiaries of LCT&S. There is the benefit to their human hosts, but one can argue equally well that they are beneficiaries of themselves. Language, culture, technology and science all create new forms constrained by their modus operandi that benefit them and enrich them. LCT&S also benefit each other as language is essential to culture and *vice versa*. Language and culture enable science and technology and science and technology in turn enrich language and culture. Science and technology cross-fertilize each other.

Are LCT&S autocatalytic is the sense that the elements of each catalyze each other's production. Words create new words and new meanings through rhetorical tropes such as metaphors, metonymy, synecdoche and irony. Grammaticalization gives rise to new syntactical structures. Cultural forms autocatalyze each other. Technologies combine to create hybrid forms from which new technologies emerge. Every breakthrough in science gives rise to new problems, the solution of which give rise to

more scientific results, in a never ending procession of new ideas. Revolutionary science once it solves a problem becomes normal science until it finally encounters a new phenomenon it cannot explain and the cycle of Kuhnian revolutionary and normal science begins all over again. It is a spiral.

20. Conclusions

Language, culture, technology and science are activities that behave like living organisms that self-created themselves and behave like living organisms that self-regulate, self-reproduce themselves, self-correct and self-maintain themselves with the one exception that as obligate symbionts they depend on their human hosts for energy.

In conclusion the analogy between living organisms and LCT&S consists of the following points:

- all propagate their organization;
- all evolve through descent, modification and selection;
- all are emergent phenomena;
- all arise from self-organization and catalytic closure; and
- all have a form of instructional information or constraints.

References

1. Logan, R.K. *The Extended Mind: The Origin of Language and Culture*; University of Toronto Press: Toronto, Canada, 2007
2. Deacon, T. *Incomplete Nature: How Mind Emerged From Matter*; Norton: New York, NY, USA, 2012.
3. Kauffman, S. *At Home in the Universe*; Oxford University Press: Oxford, UK, 1995.
4. Christiansen, M. Infinite Languages Finite Minds: Connectionism, Learning and Linguistic Structure. Ph.D. Dissertation, Centre for Cognitive Studies, University of Edinburgh, Edinburgh, UK, 1994.
5. Deacon, T. *The Symbolic Species: The Co-Evolution of the Brain and Language*; W.W. Norton: New York, NY, USA, 1997.
6. Christiansen, M.; Dale, R.; Ellefson, M.; Conway, C. The role of sequential learning in language evolution: Computational and experimental studies. In *Simulating the Evolution of Language*; Cangelosi, A., Parisi, D., Eds.; Springer-Verlag: London, UK, 2001.
7. Chomsky, N.A. *Syntactic Structures*; Mouton: The Hague, Netherlands, 1957.
8. John, B. Computational simulations of the emergence of grammar. In *Approaches to the Evolution of Language*; Hurford, J., Studdert-Kennedy, M., Knight, C., Eds.; Cambridge University Press: Cambridge, UK, 1998; pp. 405–426.
9. Kirby, S. Fitness and the selective adaptation of language. In *Approaches to the Evolution of Language*; Hurford, J., Studdert-Kennedy, M., Knight, C., Eds.; Cambridge University Press: Cambridge, UK, 1998; pp. 359–383.
10. Newport, E.L. Maturational constraints on language learning. *Cognit. Sci.* **1990**, *14*, 11–28.

11. Newport, E.L. Contrasting conceptions of the critical period for language. In *Epigenesis of Mind: Essays on Biology and Cognition*; Carey, S., Gelman, R., Eds.; Erlbaum: Hillsdale, NJ, USA, 1991.
12. Elman, J. Incremental learning, or the importance of starting small. In *13th Annual Conference of Cognitive Science Society*; Erlbaum: Hillsdale, NJ, USA, 1991.
13. Elman, J. Learning and development in neural networks: The importance of starting small. *Cognition* **1993**, *48*, 71–99.
14. Christiansen, M.; Ellefson, M. Linguistic adaptation without linguistic constraints: The role of sequential learning in language evolution. In *The Transition to Language*; Wray, A., Ed.; Oxford University Press: Oxford, UK, 2002; pp. 335–358.
15. Geertz, C. *The Interpretation of Culture*; Basic: New York, NY, USA, 1973.
16. Cronk, L. *The Complex Whole: Culture and the Evolution of Human Behavior*; Westview Press: Boulder, CO, USA, 1999.
17. Brown, D.E. *Human Universals*; MacGraw-Hill: New York, NY, USA, 1991.
18. Goodenough, W. Culture, Language and Society. In *McCaleb Module in Anthropology*; Benjamin/Cumming: Menlo Park, CA, USA, 1981.
19. Darwin, C. *The Origin of the Species by Means of Natural Selection*; Penguin: Harmondsworth, UK, 1859/1968.
20. Logan, R.K. *The Sixth Language: Learning a Living in the Internet Age*; Blackburn Press: Caldwell, NJ, USA, 2004.
21. Kauffman, S.; Logan, R.K.; Este, R.; Goebel, R.; Hobill, P.; Shmulevich, I. Propagating organization: An inquiry. *Biol. Philos.* **2007**, *23*, 27–45.
22. Shannon, C.E. A mathematical theory of communication. *Bell Syst. Tech. J.* **1948**, *27*, 379–423.
23. MacKay, D. *Information, Mechanism and Meaning*; MIT Press: Cambridge, MA, USA, 1969.
24. Logan, R.K. What is information? Why is it relativistic and what is its relationship to materiality, meaning and organization. *Information* **2012**, *3*, 68–91.
25. Dawkins, R. *The Selfish Gene*; Oxford University Press: Oxford, UK, 1976.
26. Basalla, G. *The Evolution of Technology*; Cambridge University Press: Cambridge, UK, 1988.
27. Cziko, G. *Without Miracles: Universal Selection Theory and the Second Darwinian Revolution*; MIT Press: Cambridge, MA, USA, 1995.
28. Mokyr, J. *The Lever of Riches: Technological Creativity and Economic Progress*; Oxford University Press: New York, NY, USA, 1990.
29. Vincenti, W. *What Engineers Know and How They Know It*; Johns Hopkins University Press: Baltimore, MD, USA, 1990.
30. Levinson, P. *The Soft Edge: A Natural History and Future of the Information Revolution*; Routledge: New York, NY, USA, 1997.
31. Kuhn, T. *The Structure of Scientific Revolutions*; University of Chicago Press: Chicago, IL, USA, 1972.
32. Popper, K. *The Logic of Scientific Discovery* (originally written in German as Logik der Forschung); Routledge: London, UK, 1959.
33. McLuhan, M. *Understanding Media: Extensions of Man*; MacGraw Hill: New York, NY, USA, 1964.

34. Wiktionary, the free dictionary. Available online: http://en.wiktionary.org (accessed on 4 February 2013).
35. Maturana, H.R.; Varela, F.J. *Autopoiesis and Cognition: The Realization of the Living;* Springer: Dordrecht, The Netherlands, 1980.
36. Kauffman, S. *The Origins of Order: Self-Organization and Selection in Evolution*; Oxford University Press: New York, NY, USA, 1993.
37. Donald, M. *The Origin of the Modern Mind*; Harvard University Press: Cambridge, MA, USA, 1991.
38. Kennedy, C.K. *Approaches to the Evolution of Language*; Cambridge University Press: Cambridge, UK, 1998; pp. 44–67.
39. Bickerton, D. *Language and Species*; University of Chicago Press: Chicago, IL, USA, 1990.
40. Bickerton, D. *Language and Human Behaviour*; University of Washington Press: Seattle, DC, USA, 1995.
41. Bickerton, D. Foraging *versus* social intelligence in the evolution of protolanguage. In *The Transition to Language*; Wray, A., Ed.; Oxford University Press: Oxford, UK, 2002; pp. 207–225.
42. Bybee, J. Cognitive processes in grammaticalization. In *The New Psychology of Language: Cognitive-Functional Perspective on Language Structure*; Tomasello, M., Ed.; Erlbaum: Mahwah, NJ, USA, 2003; Volume 2.
43. Durham, W.H. *Coevolution: Genes, Culture and Human Diversity*; Stanford University Press: Stanford, CA, USA, 1991.
44. Deacon, T.; Cashman, T. Teleology *versus* mechanism in biology: Beyond self-organization. In *Beyond Mechanism: New Frontiers in Biology and Evolutionary Theory*; Henning, B., Scarfe, A., Eds.; Lexington Books: Lanham, MD, USA, 2013.