

The Emergence of Language as an Autocatalytic Set of the Elements or Mechanisms that Make Speech Possible: An Enquiry

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It is argued that language is an emergent phenomenon that emerged from the autocatalysis of the various mechanisms that make speech and other forms of language possible, including writing, mathematics, science, computing and the Internet.

1.0 Introduction and Objective

WE will attempt to show that the origin of language or speech like the origin of life, is the result of autocatalysis and is an emergent process. Spoken language as a living organism evolved into a number of different forms. Logan (1995 & 2004b) showed that speech, writing, mathematics, science, computing and the Internet form an evolutionary chain of languages. Building on this result and following a suggestion of Mogens Olesen (private communication) we will show that not only spoken language but all of the different forms of language are emergent processes that arise through autocatalysis.

Emergence as pointed out by Hofkirchner (2002) cuts across disciplines and allows concepts like autocatalysis from one field to be used in another. Autocatalysis is the mechanism that Kauffman (1995, p. 49) used to explain the emergence of life: “A living organism is a system of chemicals that has the capacity to catalyze its own reproduction.” An autocatalytic set of chemicals is a group of organic molecules where the catalyst for the production (or really reproduction) of each member of the set is contained within the set itself and as a result the system can, in the presence of a source of energy and the basic atoms needed to build organic compounds, become a “self-maintaining and self-reproducing metabolism”, i.e. a living organism. A key idea in Kauffman's approach is that the members of the autocatalytic set self-organize and, hence, bootstrap themselves into existence as a set with an identity and properties different from the individual members that make up the set and hence is an emergent system. The system is emergent because its properties cannot be predicted from, derived from or reduced to those of the components of which it is composed.

An autocatalytic process is one that catalyzes itself into a positive feedback loop so that once the process starts, even as a fluctuation, it begins to accelerate and build so that a new phenomenon emerges. As a self-organizing agent, the living organism is an emergent phenomenon, because its properties cannot be reduced to those of the components of which it is composed.

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We will make use of a more generalized form of autocatalysis and suggest that any set of mechanisms or ideas that catalyze each other's existence is an autocatalytic set—an autocatalytic set of mechanisms or ideas. In the case of language we therefore posit that language is the result of an autocatalytic process among the various components of which it is composed and like a living organism has the “capacity to catalyze its own reproduction.” Language is collectively an autocatalytic whole.

We further posit that as such language is an emergent phenomenon, as its properties cannot be predicted from, derived from or reduced to those of the components of which it is composed. If we were to describe all of the mechanisms of language we would still not be able to explain its origin because language is more than the sum of its mechanisms.

We also join with Morten Christiansen (1994) and Terrence Deacon (1997) in assuming that human language can be treated as an organism that evolves like a living organism. Language is not actually an autonomous agent like a living organism because it does not metabolize a source of energy but it does reproduce itself in the fashion of a meme as introduced by Dawkins (1989). Christiansen and Ellefson (2002) have correctly identified language as “a kind of beneficial parasite—a nonobligate symbiant—that confers some selective advantage onto its human hosts without whom it cannot survive.”

Kauffman et al. (in press) have shown that a living organism has the capability of propagating its own organization and this constitutes its biotic or instructional information. Language also propagates its organization (ibid.), which reinforces Christiansen's (1994) notion that language can be treated like an organism.

2.0 The Components of Language and The Faculty of Language in the Narrow (FLN) and Broad (FLB) Sense

WE begin our discussion with spoken language, leaving our treatment of the notated languages of writing, mathematics, science, computing and the Internet to later on. As pointed out by Tecumseh Fitch (2005, p. 194) to understand spoken language and in particular its origin and evolution one must consider all of the components that make up speech or make speech possible.

As recently stressed (in) Hauser et al. (2002a), it is unproductive to discuss ‘language as an unanalyzed whole’. Thus a critical first step in analyzing language evolution is to distinguish among its various component abilities. Most generally, any mechanism involved in language is part of the faculty of language in a broad sense (FLB). Mechanisms that are both specific to language and uniquely human can be termed the faculty of language in a narrow sense (FLN), which is a subset of the FLB. The contents of the FLN must be determined empirically rather than a priori (ibid.).

The components of language without which it could not exist include the following elements: vocal articulation, vocal imitation, phonemic generativity (the ability to combine phonemes), lexical (or word) creation, morphology, conceptual representation, comprehension, a theory of mind, joint attention, altruistic behavior, syntax especially recursion, grammaticalization, and generativity of propositions. It should also be noted that speech also serves two functions, that of social communication, and conceptualization or a medium for abstract thought. We shall return to this dual aspect of language later in this paper.

Of the components listed in the above paragraph almost all of them belong to FLN, only vocal articulation and vocal imitation are part of FLB only. Many animals are capable of vocal articulation but have a limited range of signals that they can produce which is not more than 20 or 30 distinct sounds and they cannot use these signals generatively, i.e. make a combination of two signals to produce a new third signal. Some animals such as parrots, myna birds, harbor seals, bats, whales and dolphins are capable of vocal imitation (Fitch 2005, p. 197). It is important to note, however, that our closest relatives in the animal world, the great apes, do not possess this capability. Human vocal imitation was not therefore inherited genetically but developed sometime during the evolution of genus Homo.

3.0 The Emergence of FLN from the Pre-Human Components of FLB

RATHER than defining FLN as a subset of FLB as does Hauser et al. we shall define two new sets L_1 and L_2 . L_2 is the same as FLN but the set L_1 consists of those components of FLB that are not also members of FLN. ($L_1 = \text{FLB} \text{ minus } \text{FLN}$ and $L_2 = \text{FLN}$). The set L_2 consists of all those components that makes human language possible and is uniquely human. The set L_1 also contains components that makes human language possible but consists exclusively of those components of FLB that are pre-human and as such includes all the pre-adaptations for members of the set FLN or L_2 . With this definition of L_1 and L_2 , we suggest that the set L_2 emerges from the set L_1 in the classical sense of emergence since the properties of L_2 cannot be predicted from, derived from or reduced to those of L_1 . This emergence parallels the emergence of life from organic chemistry for example.

Using Philip Clayton's (2004) description of the emergence of a level L_2 from a less complex level L_1 , it becomes clear that human language is an emergent phenomenon and L_2 or FLN emerges from L_1 or FLB – FLN. Clayton describes the relationship between two levels L_1 and L_2 where L_2 emerges from L_1 as follows:

For any two levels, L_1 and L_2 where L_2 emerges from L_1 ,

- (a) L_1 is prior in natural history.
- (b) L_2 depends on L_1 , such that if the states in L_1 did not exist, the qualities in L_2 would not exist.
- (c) L_2 is the result of a sufficient complexity in L_1 . In many cases one can even identify a particular level of criticality which, when reached, will cause the system to begin manifesting new emergent properties.
- (d) One can sometimes predict the emergence of some new or emergent qualities on the basis of what one knows about L_1 . But using L_1 alone, one will not be able to predict (i) the precise nature of these qualities, (ii) the rules that govern their interactions (or their phenomenological patterns), or (iii) the sorts of emergent levels to which they may give rise in due course.
- (e) L_2 is not reducible to L_1 in any of the standard senses of 'reduction' in the philosophy of science literature: causal, explanatory, metaphysical, or ontological reduction. (ibid., p. 61)

Taking L_2 to be FLN and L_1 to be FLB - FLN then each of the 5 conditions that Clayton articulates are satisfied.

- (a) L_1 certainly took place before L_2 .
- (b) L_2 would not be possible without L_1 as L_1 contains the pre-adaptations of L_2 .
- (c) L_2 is certainly more complex than L_1 .
- (d) One cannot predict on the basis of animal signaling the emergence of the various manifestations of human language such as the generative grammar of spoken language and the evolution of spoken language into writing, mathematics, science, computing and the Internet (Logan 2004b).
- (e) Human language cannot be reduced to animal signaling in any of the senses of reduction identified by Clayton in (e) above.

4.0 Autocatalysis and the Emergence of Language

IN order to complete the argument that the emergence of spoken language is due to the autocatalysis of its components we have to demonstrate that the components or subsystems that make up language that we identified in 2.0 catalyze each other. If human language is an emergent phenomenon as I believe we have just demonstrated using Clayton's definitions it explains why theories of the origin of language that do not take into account all of the components or subsystems that make up language have proven to be less than satisfactory.

I believe that as has been suggested by Fitch (2005) that "analyzing language evolution" it is necessary "to distinguish among its various component abilities". I also agree that "it is unproductive to discuss language as an unanalyzed whole," but I believe that looking at language as an analyzed whole, a non-linear dynamic system has great merit. The course that I believe will be most productive is to look at each of the components or subsystems of language and the system of language that emerges from the autocatalytic interactions of these components. I will attempt to show how some of the components of language catalyze the emergence of other components. I do not claim to be able to execute a complete analysis of the dynamic system of language and its components but hope I that by providing a few examples I may be able to point the reader in a direction that might prove fruitful with time.

The term catalysis arises most naturally in chemistry and was used to great effect by Kauffman in his model to explain the emergence of life as the autocatalysis of organic chemicals. We would like to suggest that the analog to autocatalysis that might be most appropriate when considering the evolution of *Homo sapiens*, the most advanced species in the biosphere, is co-evolution. By autocatalysis we mean that as one function or mechanism required for language develops it creates an environment that facilitates the development of other mechanisms equally essential for language. This is the sense, we believe, in which we can use the term autocatalysis to describe how the various mechanisms necessary for the emergence of language might have bootstrapped each other into existence, i.e. this is how the various mechanisms might have co-evolved.

5.0 The Co-evolution and Autocatalysis of the Communication and Cognitive Functions of Language

BEFORE examining the co-evolution and autocatalysis of the mechanisms and components of language we will first demonstrate how the two functions of language, communication and cognition, co-evolved and at the same time provide the reader with

our model for the origin of language. Our earliest human-like ancestors, whom we will refer to as hominids, emerged in the savannas of Africa, where they were easy targets for various predators. To defend themselves from this threat as well as to increase their food supply they acquired the new skills of tool making, the control of fire, group foraging, and coordinated hunting. These activities resulted in a more complex form of social organization, which also increased the complexity of their lives. At first, this complexity could be handled through more sophisticated percept-based responses, but at some point the complexity became too great. Percept-based thought alone did not provide sufficient abstraction to deal with the increased complexity of hominid existence. The hominid mind could no longer cope with the richness of its life based solely on its perceptual sensorium. In the information overload and chaos that ensued, I believe, a new abstract level of order emerged in the form of verbal language and conceptual thinking.

I believe that when the complexity of hominid life became so great that perception and learned reactions to perceptions alone could not provide enough requisite variety ala Ashby Law of Requisite Variety to model or regulate the challenges of day-to-day life a new level of order emerged based on concepts. Percepts are the direct impressions of the external world that we apprehend with our senses. Concepts, on the other hand, are abstract ideas that result from the generalization of particular examples. Concepts allow one to deal with things that are remote in both the space and time dimension. If our first words were concepts then language allowed us to represent things that are remote in both space and time and, hence, provided language with what Hockett (1960) defines as displacement.

Concepts also increase the variety with which the brain can model the external world. Percepts are specialized, concrete and tied to a single concrete event but concepts are abstract and generative. They can be applied to many different situations or events. They can be combined with other concepts and percepts to increase variety in ways that percepts cannot.

What, we may ask, was the mechanism that allowed this transition to take place? Assuming that language is both a form of communication and an information processing system I came to the conclusion that the emergence of speech represented the actual transition from percept-based thought to concept-based thought. The spoken word, as we shall see, is the actual medium or mechanism by which concepts are expressed or represented. We must be very careful at this juncture to make sure that we do not formulate the relationship of spoken language and conceptual thought as a linear causal one. Language did not give rise to concepts nor did concepts give rise to language, rather human speech and conceptualization emerged at exactly the same point in time creating the conditions for their mutual emergence, which is a form of autocatalysis. Language and conceptual thought form an autocatalytic set because language catalyzes conceptual thought and conceptual thought catalyzes language.

Language and conceptual thought are autocatalytic and the dynamically linked parts of a dynamic cognitive system, namely, the human mind. A set of words work together to create a structure of meaning and thought. Each word shades the meaning of the next thought and the next words. Words and thoughts are both catalysts for and products of words and thoughts. Language and conceptual thought are emergent phenomena, which bootstrap themselves into existence.

The use of a word transforms the brain from one state to another and replaces a set of percepts with a concept. A word is a strange attractor for all the percepts associated with the concept represented by that word. A word, therefore, packs a great deal of experience into a single utterance or sign. Millions of percepts of a linguistic community are boiled down by the language to a single word acting as a concept and a strange attractor for all those percepts.

In suggesting that the first words were the strange attractors of percepts I did not mean to imply that all words arose in this fashion. I certainly believe that the first words to appear were the strange attractors of percepts, but once a simple lexicon of words and a primitive grammar came into being a new mental dynamic was established. The human mind was now capable of abstract thought and abstract concepts, which needed to be represented by new words. These new words would not have emerged as attractors of percepts but rather as representations of abstract concepts in the form of grammatical relationships among words. The first words of this nature would have been, in all likelihood, associated with grammar and categorization. Examples of the former would be function words such as: *he, she, this, that, and, or, but, if*, etc. and examples of the words for categorization would be words such as: *animals, people, birds, fish, insects, plants, and fruits*.

6.0 The Co-evolution and Autocatalysis of Mechanisms

IN this section we will provide some examples of ways in which one mechanism catalyzes another and vice-versa.

Vocal articulation, a mechanism that we share with many non-human animals is obviously ground zero for speech, but there is a controversy among linguists as to whether language began as a vocalized system as is true of all of today's languages or as a system of hand signals like the signed language of the deaf like ASL which is derived from spoken language. There are compelling arguments on both sides of this dispute. We will pursue Solomon-like neutrality and remain agnostic as to whether human language was first signed or vocalized. I personally favor the position of Merlin Donald (1991) in the *Making of the Modern Mind* in which he claims that language arose from mimetic communication consisting of hand signals, mime (or body language), gesture and non-verbal prosodic vocalization. It is therefore not a question of either hand signals or vocalization but probably a combination of both. The fact that it is almost impossible to speak without simultaneously using mimetic signals argues for the emergence of speech from both hand signaling and vocalization. The elements of mimetic communication identified by Donald (1991) belong to L_1 as we have defined it above, i.e. they are part of FLB but not FLN. While it is difficult to establish whether mimetic communication catalyzed speech, Donald (1991) has argued persuasively that mimetic communication served as the "cognitive laboratory" in which the skills for the production and comprehension of speech developed.

Vocal imitation is absolutely necessary for the acquisition of language by infants and hence the reproduction of the organism of language, i.e. the transmission of language from parents and caregivers to their children and wards. Vocal imitation obviously co-evolved with phonemic articulation, as imitation could not take place until phonemic articulation emerged. But on the other hand is it possible that vocal imitation contributed to phonemic articulation.

Phonemic generativity, lexical creation and conceptualization must have co-evolved because without phonemic generativity it would not be possible to create or produce the variety of sounds needed for the extensive vocabulary that characterizes human language. The mechanism of morphology would have also contributed to the generation of lexical items. But it was the pressure for a larger vocabulary that conceptualization generated that gave rise to phonemic and morphemic generativity and it was lexical creation that co-evolved with conceptualization, as our first concepts were our first words Logan (2000, 2006 & 2007). Phonemic generativity catalyzed lexical creation and conceptualization catalyzed lexical

creation, which in turn catalyzed phonemic generativity. All three bootstrapped each other into existence and hence formed an autocatalytic set.

Conceptual representation and **comprehension** are linked to the symbolic and conceptual nature of language as described by Deacon (1997) and Logan (2007) respectively and must, therefore, have co-evolved.

The desire to communicate verbally has been attributed to three closely related attributes of human cognition, namely, a **theory of mind**, the sharing of **joint attention**, and the advent of **altruistic behavior**. In order to want to engage in the **joint attention** that Tomasello (1998, pp. 208-09) suggests was essential for the emergence of language it is necessary to have a **theory of mind** (Dunbar 1998, p. 102), namely the realization that other humans have a mind, desires and needs similar to one's own mind, desires and needs. At the same time there must have developed a spirit of **altruism** (Ulbaek 1998, p. 41) once a theory of mind emerged so that human conspecifics would want to enter into the cooperative behavior that is entailed in the sharing of information. Theory of mind and joint attention catalyzes the social function of communication and cooperative behavior and vice-versa. The mechanisms of social communication and cognition through language also form an autocatalytic subset.

A number of authors believe that a primitive **syntax** emerged at the same time as the first lexicon. Donald (1991, p. 250), Levelt (1989) and Hudson (1984) support the **lexical hypothesis** that lexical items are the central focus of language and that they carry with their pronunciation, meaning, and grammatical and morphological possibilities all at once. For Christiansen and his co-workers syntax existed at the very beginning of language because it arose from the adaptation of the capabilities of the learning and processing of sequential information that existed before the advent of language.

Grammaticalization is a mechanism in which semantics gives rise to **syntax**. Semantics catalyzes syntax and syntax catalyzes semantics. They bootstrap each other. **Syntax or grammar** and the **generativity of propositions** share a similar dynamics.

Although we have been able to argue that certain mechanisms responsible for speech autocatalyze each other, we have still not yet tied together all of the mechanisms into one complete autocatalytic set, which constitutes human language. Hopefully, however, we have convinced the reader of this possibility and that this modest beginning will inspire others to make connections we were unable to develop.

Autocatalysis and the Emergence of the Notated Languages of Writing, Mathematics, Science, Computing and the Internet

LANGUAGE is not the passive container or medium of human thought whose only function is to transmit and communicate our ideas and sentiments from one person to another. Language is a "living vortices of power" (McLuhan 1972, v), which shapes and transforms our thinking. Language is both a system of communications and an informatic tool. Language is a dynamic living organism, which is constantly growing and evolving. Not only does spoken language grow in terms of its increased semantics and new syntactical forms it also evolves into new forms of presentation and expression.

As we stressed above language has two functions: social communication role and conceptualization or informatics role. Language = communication + informatics. As the informatics role of language expanded and became more complex with the increased complexity of human life information overloads developed that could not be resolved by spoken language.

Speech and the human capacity for memorization encountered limits as to how much data could be recorded in this manner. In this environment written language and mathematical notation emerged at precisely the same moment in time in Sumer approximately 3100 BCE. The teaching of the skills of reading, writing and arithmetic led to formal schools and teachers who in turn became scholars which led to another information overload that eventually gave rise to science or organized knowledge. Science based technology led to another information overload that led to computing and the information overload of computing resulted in the emergence of the Internet. In this manner there arose the evolutionary chain of languages consisting of speech, writing, mathematics, science, computing and the Internet. Each new language arose as emergent phenomena addressing the information overload that the languages from which it emerged gave rise to and could not resolve (Logan 2004b & 2007). Each new language incorporates all of the features of the languages that preceded it with the exception of writing and mathematics, which emerged simultaneously and each incorporates the other plus spoken language. As a result of this dynamic each new language emerges as the autocatalysis of the previous languages plus some new cognitive capacity that is stimulated by the information overload generated by the previous language. We will examine each of the languages spawned by spoken language and show how they represent the autocatalysis of the components of which they are composed which always includes the prior languages from which they emerged. We start with writing and mathematics and continue in the chronological order in which these new languages emerged.

Initially the vocabulary and grammatical structure of written language was the same as that of spoken language. But as the users of written forms made use of the new visual language they could see patterns that were not apparent to them in spoken language. They also began to realize that certain regularities were needed to avoid ambiguities that oral dialogues could easily resolve through the mimetic signals of gestures, hand signals, body language and tonality or by the listener simply asking the speaker to clarify something that was not understood. The components of written language that formed an autocatalytic set were the words and syntax of spoken language plus the visual signs used to represent the sounds of the spoken language. The first forms of written language were pictograms. Therefore the components of written language that autocatalyzed into a visual system of communication and storage of information were spoken language and visual representation. The first forms of notation were enumerations in the form of one-to-one tallies where the thing being enumerated was not specified.

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