LANGUAGE IS TOO COMPLEX TO EXPLAIN WITH A SINGLE FORMALISM: the theory of evolution and the Chaos theory, two interacting partners in the study of the evolution of language (opinion article)

Svetlana T. Davidova
https://orcid.org//0000-0001-9190-5937

The article is updated from a previous version for improving the precision in articulation of my ideas.

Abstract

Evolutionary linguistics explains the existence of language from two competing perspectives. On the one hand it is envisioned as an evolutionary process of variation and selection resulting in the formation of a Language Faculty, by some, and as cultural evolution in the formation of languages by others. The competing alternative view evokes the Chaos theory and the concept of self-organization in either biological context in explaining the formation of a language faculty by self-organization of neurons, or in language systems as the formation of sociolects and idiolects.
The present article argues that both evolutionary principles and self-organization interact at every step in an entangled interdependence in the formation and functioning of language and languages, which makes the individual participation of each difficult to pinpoint and estimate, suggesting that the evolution of language is better understood by treating the two formalisms as two interacting partners, not as alternatives.

Keywords: self-organization, language faculty, co-evolution, complexity, idiolect, sociolect

Introduction : evolution vs. self-organization, two alternative explanations for the existence of complex design

Self-organization and evolution are evoked as explanation for the existence of complex design . That said, these are two very different processes and operate in two very different ontological areas: the former in inorganic matter the later in life forms.
That said, attempts are made by some in the field of life sciences to explain complex biological properties by evoking self-organization as alternative to Darwinian evolution.
Evolution and self-organization are said to be theoretical alternatives in explaining the complexity of individual life forms and the diversity of species Longa V., and Lorenzo G. (2014) discuss various points of difference and find the two incompatible.
In the explanation of change and diversity they diverge on the following criteria:
a. pace of changes: gradual (evolution) vs. abrupt (self-organization)
b. triggers for change : external (evolution) vs. internal (self-organization)
c. direction of change : isotropic , or non-directional (evolution) vs. directional from disorder to order (self-organization).
d. products of change: change in degree as small alterations in pre-existing biological entities vs. biological innovations, change in kind
e. processes involved: competition (evolution) vs. cooperation, coordination (self-organization)
f. role of participants: passive (evolution) vs. active (self-organization)

g. levels of organization: genocentric (evolution) vs. Epigenesis and behaviour-centred (self-organization).
To sum up, changes in the biosphere are explained differently by different theories with different conceptual machinery . They all offer one vision to the exclusion of all alternatives. Importantly, the same " either or" perspective is assumed by linguists where alternative explanations are offered for the modern shape of the Language Faculty in biolinguistic, and for the shape of languages in usage-based/emergentist contexts.
Importantly, Darwin's theory is formulated for explanation of the diversity of species of life forms and , as such, reflects the fundamental properties of biological beings.
The Chaos theory is designed to explain the diversity of forms in physical matter and, as such, reflects the fundamental properties of lifeless matter.
That said, recently both Darwin's theory and the Chaos theory have been reinvented to explain a broader range of phenomena, e.g. Universal Darwinism as a universal theory explaining cultural and linguistic diversity, and the Chaos theory for explaining complex formations in biology, cognition, linguistics, cultural artifacts.
Most importantly, both Darwinism and the chaos theory are evoked as competing explanations of language as a biological organ, and languages as cultural creations.
That said, language is a highly complex phenomenon composed of multiple components of different ontological types : physical matter , e.g. sound waves, chemical substances and compounds as building blocks of the human organism, biological matter , e.g structures and systems in the human organism which participate in language-related activities, , as well as non-material, e.g. abstract concepts, all of which interact and change as they form a unique complex. This suggests that one-sided perspectives are bound to provide simplistic and incomplete explanations.
In the present paper I will offer an alternative perspective, i.e that both evolutionary principles and self-organization interact in an entangled interdependence in the formation and functioning of language and languages, which makes the individual participation of each difficult to pinpoint and estimate.

1. The original theory of evolution by Charles Darwin

Darwin's theory of evolution of species by natural selection is one of the major scientific achievements of all times. It defines diversification of life forms as alteration in heritable characteristics of successive generations. It is a three-step process and encompasses three interconnected phenomena in the living world : inheritance, variation and differential survival. Darwinian theory has offered a plausible explanation for the presence of complex design in life forms. In Darwin's theory the diversity of species is explained as resulting from series of small successive modifications in the ancestral species in response to environmental changes. These small modifications, gradually accumulated in each new generation of descendants, lead to their divergence into new species. The following summary by Schoenemann (1999) outlines the general principles of evolution in a concise and clear form:
A.Evolutionary changes are gradual, evolution is a process in which changes occur in small steps, each one of which is independently beneficial for the survival of the species, undergoing the change.
B. Evolution prefers continuity. Evolutionary changes are incremental, they are improvements

upon prior adaptations. In Schoenemann (1999) “ Evolution does not produce novelties from scratch. It works on what already exists” (p. 313)
C. Evolution prefers domain-general mechanisms as they lend themselves to modifications. In Schoenemann (2005) “...the evolutionary process does not favor the evolution of domain-specific modules...the evolutionary process itself is inevitably biased towards modifying mechanisms that are by definition more domain-general” (p.4).
D. Evolutionary changes are usually preceded by behavioural shifts as the biological entity is forced to extend the limits of its behavioural flexibility to cope with the environmental challenges . In Schoenemann (2005) “ Behavioural adaptations which require minimal genetic changes will be favoured at each step. “ (p.4).
E. Evolutionary goals are short-term solutions to local circumstances. Evolution does not have long-term plans. It is a reactionary process as it reacts to present and local circumstances and has no foresight or planning. Evolutionary change does not imply progress in absolute sense. Progress is defined only in term of survival in the local environment at a given time-period.
F.Evolution is not concerned with the good of the species as a whole, it works on improving the survival of the individual organism.
G. Organisms do not evolve in isolation. Evolutionary changes are an adaptation to some feature of the environment. Thus, evolution is a change triggered from factors external to the organism. It is a change from without. The concept of environment includes not only the physical environment but also other organisms in the ecosystem with which an organism co-evolves.

1.1. Evolution of Darwinism

Modern science has prompted various interpretation of the original Darwinian theory. Classical physics has influenced studies of evolution in portraying it as recombination of stable immutable entities which act as abstract individual entities independently of context . Mendelian heredity bares the name of Mendel who in the 19 century designed a mathematical model for describing heredity. The modern interpretation of Mendel's theory understands the organism in terms of an abstract model as a combination of discrete elements and describes heredity as “inheritance by which stable non-decomposable characters, controlled entirely or overwhelmingly by a single genetic locus, are transmitted over many generations “ (in www. medical-dictionary.thefreedictionary.com/ mendelian+ inheritance).
The Mendelian paradigm combined with molecular biological perspective on heredity furnishes the modern understanding of evolution. Mendelian use of mathematical concepts is coupled with the influence of Turing's theory of computation in modern biology. Concepts and principles of computation are borrowed from Turing where a finite and predetermined set of abstract symbols automatically combine according to a finite number of equally predetermined rules results in infinite number of combinations. In this context evolution is defined as a computation process where a finite number of basic discrete units of DNA molecules combine and form the diversity of life forms. Key concepts are DNA, genotype, phenotype.

1.2. Evolution as a multidimensional process

The evolutionary process is a complex interaction and interdependence of evolutionary inheritance in various contexts. Jablonka, Lamb (2005) distinguish 4 dimensions : inheritance at the genetic level, epigenetic inheritance, inheritance in developmental routines, inheritance of behaviour.
The term " epigenesis" was coined by Waddington in the 1940s and refers to processes of formation of the new organism, the phenotype, through interaction of the genome with the environment at the molecular level. The building of the new organism starts from the formation of a new genome by copying of the parental genomes. The information about the post- fertilization process of building of various organs and tissues of the new organism is contained in the so called regulatory genes which follow established pathways of turning on and off specific chemical processes at specific time-frames depending on the type of tissue . The epigenetic routines are also referred to as " canalization" of the developmental process to follow established pathways. The activities of the regulatory genes, their time schedules , i.e. patterns of epigenetic development, are preserved by the cell memory and passed on, so the new daughter cells follow the same developmental routines . Thus, epigenetic routines are also inherited.
In addition, experience can trigger alterations in the genome. This idea was first proposed by Mark Baldwin and is known as the Baldwin effect. Baldwin argues that a behaviour , which initially consumes much effort and time to learn, can gradually become easier to master with every new generation to the point when very little or no learning is required and the behaviour essentially becomes instinctive. Baldwinian evolution is an intelligent solution nature has found to successfully respond to unpredictable environmental challenges.
In addition, behaviour routines are copied/inherited by learning. Individual animals learn from experience and social animals learn from conspecifics. Learned behaviours are not inherited by the genome, they are learned anew by each new generation. The process of learning from conspecifics is defined in Darwinian terms as inheritance of knowledge by copying of information from one brain to another. Similar to other types of inheritance the process of copying is subjected to errors which creates variation. Behavioural inheritance follows the general principles of a Darwinian process i.e., as part of the learning process behavioural innovations are selectively perpetuated given survival superiority to alternatives.
In sum, evolution is a highly complex process where a number of sub-evolutions interact to determine the observable diversity of life.

"...there are several types of heritable variation ...transmitted in different ways , and selection operates simultaneously on different traits and at different levels of biological organization. " (Jablonka, Lamb, 2005, p. 276).
In sum,
" Something like evolution can occur in each dimension. But...we are not made up of four neat and separate dimensions, we are a messy complex. And it is the complex that evolves " (Lamb, Jablonka, 2005, p. 231).

1.3. Universal neo-Darwinism

D. Hull (1988) proposes a generalized theory of evolutionary change where the theory of evolution by natural selection is used as a template for understanding similar processes in other phenomena. The basic principles of Darwinism are incorporated in an overarching general theory of evolution, which defines evolutionary changes in abstract terms and aims to understand processes of change in any context . Hull's generalized theory of evolution , in analogy to biological evolution, understands evolution in general as two different processes, of replication and selection, performed by two different entities with two different roles in the evolutionary process : replicators, which are copied, and interactors, which interact with the environment and are subjected to selection. He maintains the separation between replicator and interactor but points out that , like in biology, the roles of replicators and interactors can be assumed by different entities at different levels of structural complexity. For example, genes, chromosomes and species can be both replicators and interactors.

2. Darwinism as explanation for language evolution

In evolutionary linguistics the evolutionary theory is evoked in two contexts: in biolinguistic context for the phylogenesis of the Language Faculty and in usage-based approaches for the glossogenesis of languages.

2.1. Phylogenesis of a Language Faculty

Pinker and Bloom (1990) were the first to suggest Darwinian explanation for human linguistic abilities via gradual incremental alterations in the genetic makeup of an organism as adaptations to environmental changes in the form of a language instinct/language organ/language faculty, a cognitive structure specialized for processing of Universal Grammar and located in Broca' s region of the brain.

To remind, the functioning of the language algorithm is premised on the pre-existing lexicon from where words are selected and combined by an operation Merge. Under the latest version of minimalism it is hypothesized to produce grammars with the properties defined by the Principles and Parameters /Government and Binding approach. These are as follows: **a**.It produces hierarchically organized structures. **b.** All operations are cyclical. **c**. All operations are local. **d**.Control operates on deficient clauses which contain elements in need of proper case assignment . **e**.Rules are structure-dependent. **f.** Movement is always local, upwards, structure-preserving and under C-command configuration. **g.**Case and agreement apply at Xo and XP, but not at X' level. **h.** Pronouns and reflexives are in complementary distribution and are subjected to binding principles. **i.** Grammatical structures must be semantically interpretable. **j.**The output of each cycle of linguistic computations is fed into two interfaces, the Logical form and the Phonological form, which produce meaningful and pronounceable pieces of usable language. The Minimalist views on the Language faculty are outlined in detail in Chomsky 2005, Hornstein 2018 and elsewhere.

Initially the existence of a language faculty in the human brain was explained in terms of genetic evolution and the discovery that a single gene, FOXP2 was directly responsible for complex linguistic functions. Lately other genes, e.g. ROBO1, ROBO2 and CNTNAP2 were determined to be implicated in language-relevant functions, in recognition of the pervasive pleiotropy of the organism(Dediu, Levinson, 2018).

A multistage hypothesis (Jackendoff 2002; Cullicover, Jackendoff 2005; Jackenfoff,

Wittenberg 2014) envisages phylogenesis of language as a gradual multistage process where cognitive changes in the homo lineage are reflected in language systems of gradually increasing grammatical complexity and culminating in modern multileveled structure of language.
To note, attempts of evolutionary explanation of the language faculty by linguists reveal misunderstanding of fundamental evolutionary principles. For example, as a general characteristic of the evolutionary process , a genetic mutation survives the selection process if it produces phenotypes capable of surviving and reproducing at rates higher than the competition. That is, a language capacity for complex language , in order to be competitive, must prove not just its utility but its reproductive superiority, compared to alternatives. That said, there is no evidence for connection between language skills and fertility.

“ ...the claim that greater rationality and linguistic ability lead to greater offspring production is largely a modern prejudice” (Lewontin, 1998, .p. 22).

Importantly, the generative stipulation that the rules of grammar determined by the language faculty are arbitrary, i.e. unmotivated by language use, one of the most foundational assumptions of the innatist argument, contradicts claims for its selective advantages and reproductive superiority. Similarly, the vision of language faculty as uniform, i.e. each individual brain has an identical copy of it, disregards a fundamental aspect of the evolutionary process, i.e. variation on which selection operates, which injects additional confusion in the generative argument. In addition, the assumption of pre-existence of a lexicon, i.e. a cultural invention, as a pre-condition for the bio-program to be turned on has no known parallels in life sciences and is , I suspect, a biological impossibility. Importantly, the generative/ biolinguistic approach and its conceptualization of the language faculty as a biological tissue in terms of artificial systems reveals misunderstanding of life forms, the human mind and evolution by assuming that somehow a biological entity can violate the laws of life forms and still remain a biological entity.
In sum, the generative/biolinguistic conception of the language faculty is in contradiction with evolutionary principles which limits the possibility for delivering reliable insights and understanding of the evolution of language.

2.2. Darwinian principles and glossogenesis of modern languages

Hull's theory (1988)is applied for explaining changes in various spheres : life forms , cultural practices (from technology, farming, fashion, to institutions , language). Dawkins (1976) proposes that cultural evolution can be understood with Darwinian principles of variation and selection. He introduces the concept of 'meme' as unit of cultural evolution analogue to the gene in biology.
In linguistics there is a long tradition in defining language diversity in biological terms as diversification of languages from a common ancestor. It begins with Darwin himself who has written about the analogy of languages to species. (Darwin, 1871, referenced by M. Studderd-Kennedy, 1990). This tendency is continued by 19th century European linguists and later, with the discovery of the genome and reinterpretation of Darwin's theory of evolution in terms of genetic evolution as Mendelian genetics, the tradition of defining language in biological terms

has been reinterpreted by finding analogies with genes in the domain of language. Scholars who see parallels between languages and biological beings look for similarities between biological evolution and changes in language systems and assume that the principles of Darwinian evolution by variation and natural selection can be borrowed to explain historical changes in the language systems over time, a process termed glossogenesis.

In the usage-based approaches principles and methods of modern genetics are borrowed into linguistics in effort to understand change in language systems as linguistic forms are likened to genes and language systems to genomes. In this way genetics is applied for determining the phylogeny of languages as branches of language families.
Moreover, some find parallel between evolution in human populations and languages. This lead to the hypothesis of the African Eve, which argues that all humans are descendants of a small population which lived in Africa some 150,000-200,000years ago(ya) and all modern languages have branched out of the so called protoworld, or " mother tongue" , the language of this ancestral population, whose traces, seen as linguistic genes, are said to be preserved in modern languages, was proposed by Merritt Ruhlen (1996) and Ruhlen (1992).
The argument has been criticized and is not accepted by most linguists.

The theory of grammaticalization understands glossogenesis/ language change as change in the individual linguistic entity where each has its own evolutionary path, although most follow a general pattern : lexical (content) word>grammatical word> clitic>inflectional affix.(Heine and Kuteva 2007)

As an alternative to the gene-centred perspective on lifeforms and languages, the population perspective on organisms by E. Mayr (2001). A population perspective defines languages in therm of populations of idiolects : if different language varieties are mutually intelligible they belong to the same language. In analogy to species' reproductive isolation which results in species diversification , communicative isolation leads to loss of intelligibility which marks the difference between language varieties and different languages. In this context a language is defined in terms of the linguistic interactions of a community.
Croft's model of language evolution (2000) adopts the population perspective on evolution in the study of linguistic phenomena. Here language is the set of linguemes, abstract linguistic entities, e.g., a phoneme, a word in its conventional phonemic structure , syntactic features, etc. are formed by conventions and reside in minds. They are replicators, the linguistic equivalent of the gene. Utterances , the linguistic equivalent of biological bodies are the interactors which, by their interactions make possible the replication of linguemes. Thus, the replication of linguemes happens during their use in communication as utterances/interactors.

In Croft glossogenesis follows the general principles of evolution:

a. variation : variation in various levels of language use is pervasive: 1. there is diversity of idiolects, 2. among sociolects, as sociolinguistic diversity, motivated by various social factors: age, gender, class, 3. variation within idiolects : in phonetics, lexicon and grammar as the same person is found to use different linguistic devices at different occasions in expressing the same idea.

b. competition : in language two or more vocabulary items are used as alternatives to encode the same concept (synonyms), or various syntactic structures are alternatively used to describe

the same event . For example: “ He decided to leave : it was getting late.” vs. “ He decided to leave because it was getting late.”
c. inheritance : some linguistic forms are persistently used over generations , which makes possible the understanding between generations.

2.3. Language change is not evolution.

Although many scholars, starting from Darwin, have pointed at similarities between the processes of change in biological and linguistic contexts , prompting the transplant of conceptual machinery from biology into linguistics, there are also significant differences. For example :
a. The mechanisms of inheritance in linguistic and biological contexts differ significantly. In phylogenesis acquired characteristics are not transmitted to the next generation, while in glossogenesis such transmission is the norm, since linguistic innovations of predecessors are perpetuated by the new generation. Thus, biological evolution is Darwinian-Mendelian, glossogenesis is Lamarckian.
b. In phylogenesis the genomes of the parents are inherited in their entirety at the single point of conception, while linguistic items are learned piece-meal at different points of the learning process.
c. Linguistic entities are transmitted (inherited) via language use , that is, mediated by communicative interaction as conscious behaviour, while genes are inherited directly, by instinctive urge to produce offsprings.

d. In genetic transmission the offspring has no active role in the production of the new genotype, while in the formation of the idiolect the learner is active participant by making choices in reflection of one's individuality.

e. In life forms an organism inherits characteristics of two parents, while in the formation of the idiolect multiple community members , e.g. parents, extended family, neighbours, teachers etc. make linguistic contributions. Moreover, in biological organisms the offspring inherits the totality of the parents' genomes, while in the idiolect the contribution of the parents' idiolects is one of many.

f. In life forms genetic variation is produced by recombination of the pool of parental genes, while in the formation of the idiolect the learner can introduce his/her own innovations , although these are restricted by what would be considered acceptable by the community. The formation of the idiolect, then, is a creative process and a reflection of one's individuality as a creative entity.

g. In phylogenesis copying errors are rare and the genome is highly conservative, while languages display a much higher intra-lingual diversity of idiolects and sociolects which amplifies the potential choices for selection.

h. The selection factors in phylogenesis and glossogenesis are very different. Although biological factors play a role in both processes, in glossogenesis the social and cultural environment is of primary importance.

i. The number of species of flora and fauna is in the millions, while diversity of languages is highly constrained at about 7000.

In short, evoking Darwinian principles in explaining diversity and change in languages, although provides some valuable contributions in extending our knowledge of the world to languages and their past histories, is not able on its own to provide a full picture as it ignores the role of biological evolution of the human language capacity, in whatever form it will be determined to exist in the human body.

3. The complexity paradigm

Given that the theory of evolution is well known as is application of evolutionary principles in linguistics, hence, the evolution of language, a major topic of research, further comments on that are, I think, unnecessary. On the other hand, the complexity paradigm is fairly recent and much less known to linguistic circles which demands some detail of exposition. It was initially meant to explain the appearance of complex organization in inorganic matter.

A system is complex if it is composed of multiple component parts each semi - independent, but connected by membership in an integrated whole. Complex systems are emergent, and thus, are historical entities and as such are unique. Emergent systems are multicomponent and hierarchically organized, where each new level of complexity is organized differently (Corning,1998, 2002,)

A complex system is situated at the cusp between order and chaos, that is, it is neither completely predetermined and predictable, nor completely chaotic and unpredictable. Under certain conditions order can be replaced by chaos and vice versa, a chaotic system can self-organize, i.e. form structure. This means that order is flexible and alterable and also that order and disorder/chaos naturally co-exist and create one another. This brings possibility of change, which is inherent in nature (Heylighen 2008). In this context change is explained with series of spontaneous unmotivated events of emergence of novelties . The theory defines complexity in terms of simple interactions among multiple individual entities, which produce results different from the actions of individual entities in isolation, and by which interactions complex internal organization is produced, as in chemical compounds, e.g. $H2O$ from atoms of H and O.

In short, the whole is different from the sum of its parts and collective complexity spontaneously emerges from individual simplicity where simplicity is defined as lack of internal organization, that is, something is simple if it is indivisible and homogeneous .

As a general term " emergence" means an unprecedented and sudden event of appearance of groundbreaking novelties in nature by spontaneous interactions of individual entities, giving rise to well organized new entity, a " radical novelty". In other words, " rule-like reality can emerge from apparently unregulated behaviour. "(Ellis, 1998, p.643), producing novelties with unique structural properties , not predictable from antecedent conditions and impossible to anticipate, implying a clear difference of before and after states, a qualitative change. Emergent phenomena are the result of self-organization, i.e." Emergence is what self-organizing processes produce." (Corning 2002)

Although emergence implies a change in kind within a short time, it is actually a three-stage process : synergy, self-organization, emergence. Initially occasional synergistic interactions, if repeated, form initial patterns of internal organization, which, if solidified, result in the emergence/appearance of novel stable integrated wholes. Thus, a newly formed complex novelty is produced by a succession of events where cooperative behaviours of ever increasing strength build upon one another, producing permanent organization. Self-organization is a key

concept in the complexity theory. It is a general property of complex systems, where in a singular event global organization in form of patterns emerges from interactions at a lower, local level, or "...well defined patterns emerge spontaneously giving rise to order in a system from previous chaos."(Longa , 2001, p.4) A self-organizing system is one capable of self-control. Order is defined as a state of a system which is describable by fewer rules, established by the coordinated behaviour of interacting entities which, initially acting chaotically as independent individuals, under certain conditions coordinate their behaviours in a pattern and become members of a unity.
The following characteristics are defining features of self-organization.
1. Absence of external cause. The process of internal organization and structure-creation is prompted by internal pressures, quite unlike the process of adaptation in biological evolution , where external forces from the environment are the cause of change .
2.Critical mass. The emergence of structure takes place when the number of participating elements reaches a critical mass and as a result "...a quantitative change triggers a sudden qualitative change: the emergence of order. " (Longa, 2001, p.12).
3. Absence of internal centralized control , instead control is " distributed" as all participant units have some influence over the final outcome, the shape of the new pattern as their interactions at a local level result in the emergence of unifying global patterns, i.e. "The local alignment has expanded into a global order."(Heylighen, 1999)
Magnetism , herds of sheep, flocks of birds, ecosystems, stock markets, etc. , all display ability to spontaneously organize into self-regulating systems .
4. Non-linearity. Unlike linear systems, where the effect is proportionate to the cause, in non-linear systems this relation is disproportionate and unpredictable. This means that small changes could have enormous effect and vice versa. This follows from the so called " feed-back " : each component is connected to each one of the rest, so that a change in one component causes changes in all of the rest which, in turn, comes back full circle to affect initiator of the change. The feed-back can be positive or negative at different places in the system, which makes the final outcome unpredictable.
5. A self-organizing system is closed, or isolated from the surrounding environment, i.e. self-organization happens when a number of individual entities find themselves isolated form the surrounding environment and in close contact, where prolonged interactions result in changing individual entities into components or members of a unity.

" ... Organizational closure turns a collection of interacting elements into an individual, coherent whole" (Heylighen, F. 1999 p.11)

That said, the isolation is nevertheless partial as influx of energy from outside does occur, which, crucially, is the source of disorder, or chaos, and the trigger for self-organization, or order, i.e. the emergence of a new entity with new properties, non-reducible to the sum of the properties of the participating components. There are no universal patterns of self-organization and no predetermined blueprint : the process is by definition a spontaneous, unpredictable and creative one, while following simple, general and universal principles of interaction.
To recap , the main characteristics of a complex system can be summarized as follows:
1. It is composed of various semi-independent parts which exist and interact in coordinated way as components of a unified whole. The interactions among the components produce additional

value over and above the value of the independent actions of the same entities as individuals.
2. The components of a complex system change as a result of interactions resulting in internally organized complex entity.
3. Internal changes may not result in a change in the overall functioning of the system which under certain conditions remains stable. Nevertheless, when a breaking point is reached a swift change in the organization of the system takes place.
4. As internal changes are not detectable from outside, the future states of the system are difficult to anticipate with certainty, only with various degrees of probability, e.g. the trajectory of future patterns is likely to be a continuation of a trajectory formed in the past. Prediction is only an estimation of possibility, not certainty.
Lately the complexity paradigm was reinterpreted for understanding changes in the biosphere, by Gould, Lewontin (1979) and others.

3.1. Locating life at the edge of chaos

In modern science the theory of evolution by natural selection, initially designed by Darwin is recognized as the best explanation for the diversity of life forms. In recent years the chaos theory is proposed as an alternative hypothesis to Darwin's theory, most notably by Kauffman (1995 and elsewhere). The chaos theory states that universal laws of self-organization explain the emergence of complex organization and its application to biological forms would imply that life in some universal form as inevitable and ubiquitous throughout the universe, predetermined by God-like principles, given that self-organizing life would exist irrespective of the environmental conditions on a specific planet, in rejection of Darwinian principles of adaptation to an environment. This suggests the direct implication that astronauts would find life forms on Mars, the moon and everywhere else, similar to these on earth, i.e. in demonstration of a universal " body plan" with some minor variations explicable with different combinations of " parameter tuning ". As per Kauffman life is " natural outgrowth of the world in which we live".(Kauffman, 1995, p.26) And most importantly, Kauffman suggests that life has emerged at once in its fully modern form.

" Life emerged, I suggest, not simple but complex and whole, and has remained complex and whole ever since" (Kauffman, ibid. p. 25-26)

My take on the argument that life on earth can be explained in the context of the Chaos theory is as follows: if life is the inevitable result of the spontaneous formation of order , it would be fairly easy to demonstrate that in lab experiments. I know of no such demonstrations so far. Moreover, if all species, simple and complex, emerged simultaneously, this implies that human species are not 250,000 years old, but human speciation is as old as life on earth, i.e. 4 billion years old. In addition, it must be anticipated that extraterrestrial intelligent life, very similar to ours is a given. The fact that visits to near by planets have not found extraterrestrial life could possibly suggests that it cannot be detected by human astronauts and/or equipment. In any case, how an empirical prof of the hypothesis would look like?

Others, Camazine (2001), see also Seeley, 2001)argue that self-organization is preferred in the diversification of life forms as in some aspects of the evolutionary process change is easier to achieve by self-organization. For example, in social species selection favours products of

self-organization in physiology and behaviours, as opposed to genetically pre-specified patterns of development for the following reasons:
a. Blueprints are complex , self-organization is simple.
The formation of genetically based complex behaviours (blueprints) usually involves genetic changes of great specificity and precision which are difficult to implement by development. In contrast, the genetic instructions for coordinating group behaviours are simple and usually more general. Nature prefers simplicity.
b. Blueprints are costly, self-organization is cheep.
The formation of blueprints demands more energy costs due to its specificity. Self-organizing systems are more economical to develop .
c. Central control is difficult to establish in social species by genetically determined avenues for information transmission and coordination . In large animal groups the formation of a genetic recipe must include instructions for the individual animals to work together in a coordinated way and each individual genotype must be specified for a role in collective activities (e.g. construction in beavers or nest building in birds) considerable cognitive complexity in individual members is required. In addition, the establishment of central control in the form of a leader is hampered by the fact that animals usually communicate at a local level and , for example, in a group of several million ants, the authority of a leader is not possible to establish due to lack of innate patterns of information transmission for which even more genetic complexity is needed. Coordination of individual behaviours at a local level is much easier to establish.
d. Blueprints are stable and inflexible, self-organization is adaptable. In this sense blueprints present a problem in social species as the individual behaviour must constantly adapt to the behaviours of group members.

4. Self-organization and evolution, theoretical rivals in explaining complexity of biological form

As mentioned above, in modern science the internal complexity and diversity in life forms on earth is explained with two alternative theoretical platforms, evolution and self-organization . Darwin's theory of evolution defines life as a tree where species branch out from a common ancestor following a lengthy process of accumulation and differential inheritance of minor differences, causing diversity in the phenotype. At the centre of evolutionary processes is the genome, the repository of instructions for the formation of the organism. The theory of complexity is usually credited with explaining the provenance of complex entities in the non-organic world. The former is a process which affects independently functioning individuals, the later, individuals acting in coordination as members of a larger unity. In biosphere environment is crucial as trigger for evolutionary changes, while complex entities of physical matter are dependent on initial conditions as triggers and progress independent of the environment. Moreover, the standard version of the evolutionary theory , the Modern Synthesis, explains changes in biological bodies as top-down, or from genome to phenotype. In self-organization changes are from bottom up, thus, locally emerging patterns become globalized. In addition, evolution of species is expected to be gradual and incremental over long time periods, while self-organization usually implies a swift qualitative change producing complex novelties in a short time. So the two theories are different because they formalize different types of reality, thus, epistemological differences reflect ontological differences.

4.1. Punctuated equilibrium, alternative to evolution

Although the theory of evolution is currently dominant in modern science, alternative hypotheses have questioned some major tenets of the theory and proposed alternatives.
The hypothesis of punctuated equilibrium by Gould and Eldridge has emerged as a counterargument to Darwinian gradualism as explanation for diversity in life forms. (Gould and Aldridge, 1972, p. 91)
The hypothesis of punctuated equilibrium argues that abrupt shifts in the form of macro-mutations alternate with periods of relative stability which explains the gaps in the archeological record. Genetic events of such significant magnitude are assumed to occur in a single individual in spatially and as a result, reproductively isolated, usually small populations, thereby resulting in genetic unbalance or disorder in the population. Reproductive isolation provides the optimal conditions for the mutation to spread fast, making the mutant's offsprings dominant and marking the return to genetic equilibrium, hence the hypothesis of punctuated equilibrium. In this way the species diversity is explained with self-organization in the genome.
Numerous empirical examples support the hypothesis , some of the most quoted of which is the Cambrian explosion, where after a long period of stasis an explosion morphological variation and complexity took place about 550 million years ago (mya) , which gave rise to the genetic diversity found in life forms today.
A similar idea of evolution as series of dramatic transformations is articulated by Maynard Smith and Szathmary (1995) who distinguish 5 major transitions in evolution.

4.2. Laws of mathematics and a universal body plan

The complexity paradigm has originally been designed as an alternative to Newtonian physics in the study of physical matter. Efforts have been made to apply it directly in understanding change in biological systems under a reductionist approach. For D'Arcy Thompson " true science ", namely, physics and chemistry, "lay in its relation to mathematics" (D'Arcy Thompson, 1992, p. 1). A zoologist by training, he attempts to explain the properties of living organisms by universal laws of matter. He argues that universal principles of physics and geometry shape directly the morphology of life forms and applies "mathematical methods and mathematical terminology do define and describe the forms of organisms." (ibid. p. 269). In this way D'Arcy Thompson aims to explain the skeletal morphology of vertebrates and the changes it undergoes during lifetime with the influence of physical forces on the shape and physical dimensions of the skeleton. In this context physical forces interact with the properties of the organism, which creates different outcomes in different species. For example, depending on the animal's mass, velocity of locomotion , size, bodies are influenced differently by gravity, surface tension, and other physical forces, producing different outcomes in morphology of insects, birds, mammals, etc. "...there is an essential difference in kind between the phenomena of form in the larger and in the smaller organisms." (ibid. p. 36). In rejection of the evolutionary explanation for species' diversity as adaptation to local environments, he argues that diversity of skeletal proportions found in species comes down to a limited range of slight alterations, or divergences in various directions, in an otherwise universal " body plan", determined by the principles of geometry. So, the details of the skeletal morphology of a species and the changes it undergoes during development from infancy to adulthood are understood here as slight deviations from a theoretical prototype, calculated to perfection by the principles of geometry.

"our own study of organic form...is but a portion of that wider Science of form which deals with form assumed by matter under all aspects and conditions, and, in this wider sense , with forms which are theoretically imaginable" (ibid. p. 269).

In this context change in the configuration of the " body plan" is understood in terms of minor alterations or " parameter tuning", (Edelman, Denton 2007, referencing Camazine et all. 2001)
That said, the stipulation of universal body plan offers explanation for vertebrate species only, leaving the rest of biological species, e.g. plants, insects, etc. inexplicable.
Significantly, the argument for self-organizing biological matter as demonstration of nature's creativity understands self-organization as a core principle underlying organic and non-organic matter.
" We find the parsimony and beauty in the idea that the basic forms of inorganic and organic realm of nature may finally be shown to result from the same principle of self-organization immensely attractive and unifying." (Edelman, Denton 2007, p. 598).

The argument for self-organization as a determining factor in the formation of life forms as creation of novelties in self-organizing biological matter implies universality of life throughout the universe, and the hierarchy of complexity within it. In short, that life takes the same form everywhere in the universe, from DNA molecules to humans , perhaps within minor deviations from the universal "body plan". Moreover, the postulation of a universal " body plan" would answer an age-old question, are we, humans, alone in the universe, given that the architecture of the human skeleton and bipedalism is understood as a major factor in human intelligence and language, projecting human-like societies and cultures to be ubiquitous in the universe. In this sense one gets the impression that, while Darwin offered humanity a huge leap forward in the scientific understanding of biological form, the complexity paradigm reinvented the idea of universal order, traditionally attributed to a deity, substituted in modern context with the god of mathematics.
On the other hand, I suspect it is natural to look for commonalities in self-organizing systems in both non-organic and organic matter given that both are dependent on outside influx of energy, physical energy, e.g. heat in inorganic context, and food in life forms.

5. Self-organization and evolution, two contributing factors in the diversity of life forms

" ...spontaneous order...has been as potent as natural selection in the creation of the living world. We are the children of twin sources of order, not a singular source." (Kauffman,1995, p. 38).

The Chaos theory defines the living organism in terms of autocatalytic sets of molecules organized in a cell, not in terms of genetic storage of instructions and their realization in phenotypes, as in modern Darwinism. Life is envisioned here to have emerged from non-life as

soon as a concentration of the necessary chemical components is found in a closed space, making possible their interaction, resulting in self-replicating cells.
Kauffman and like-minded scholars recognize that diversity of life on earth cannot be explained only in terms of successions of speciations and extinctions, i.e. in the alternation of order and chaos in life forms. He recognizes that self-organization is a component of the evolutionary process, as self-organization creates the conditions for selection.

“ ...self-organization is a prerequisite for evolvability...there is an inevitable relationship among spontaneous order, robustness, redundancy, gradualism...” (Kauffman, 1995, p.104).

If I understand him properly, Kauffman suggests that the origins of life are in the spontaneous self-organization and self-replication /autocatalysis at molecular level where during the replication procedure small alterations in the internal configulation of self-replicating molecules, can occasionally occur, not sufficient to trigger dissolution of order into chaos, i.e. “ without veering into randomness” (Kauffman, ibid. p. 44). The imperfections in the self-replicating process produce variation, which triggers selection process, thereby providing the conditions for a Darwinian evolution to work. Thus, life is formed at the edge of order and chaos. In this context, natural selection “ finds its role as the molder and shaper of the spontaneous order for free.” (Kauffman, ibid. p.49). So, the source of variation produced by errors in self-replication of molecules, i.e. bio-chemical elements, suggested by Kauffman, is highly similar to variation produced by genetic replication in Modern Synthesis. And, again, if I understand him correctly, he suggests that the evolutionary process is pre-conditioned on a pre-existing order. Similarly, in V. Longa (2001)self-organization is seen as a contributing factor, as a source of variation on which selection operates in both biological and cultural evolution.

“ Selection is a filter that rejects the utter failures…To sum up, selection does not originate complexity; instead, it operates on it…As Kauffman puts it , “ that which is self-organized and robust is what we are likely to see preeminently utilized by selection” (V. Longa, 2001, p.7)

Similarly, Batten, Salthie, Boschetti (2008) argue that the relationship between self-organization and natural selection is one of mutual cooperation unfolding in a three-stage process :
1. self-organization produces internally complex organisms upon which selection acts: thus, self-organization provides the starting point for the evolutionary process.
2. at the next stage the outputs of selection provide input for the next round of self-organization , thus natural selection acts as a constraint on self-organization.
3. complex organisms produced by self-organization compose the environment to which organisms adapt and which is the context for natural selection to operate. In short, these are two complementary processes.
In addition, Oudeyer (2011) finds that self-organization interacts with evolutionary processes in creating diversity of life forms in that :
a. life starts with the formation of a cell by self-organization, that is, impulsive internal structuring
b. self-organization further produces complex biological entities which become choices for

selection.

“ Self-organization provides a catalogue of complex forms distributed over a landscape of valleys in which and between which natural selection moves and makes its choices...”Oudeyer, ibid.

c. emergent complex biological entities delimit the available options for the next selection cycle (Heylighen, 1999). Johnson and Lam (2010) argue that self-organization plays a “ subservient role in the evolution of biological complexity” (Johnson Lam 2010, p.881) where the conditions for self-organization to work must be created, maintained and regulated by the organism. The role of selection is found to be crucial as, although selection does not create complexity, it “discovers complexity”(Johnson, Lam 2010) , i.e. identifies products of self-organization with adaptive potential, and creates the right conditions for self-organization processes to take place. Further, adaptation works on their improvement. That is, self-organization and selection feed off one another in entangled interdependence.

5.1. Self-organization and complexity in life forms, reductionism and beyond

Scientific study of reality has begun in Ancient Greece and ever since the goal of science has been to uncover the eternal, immutable order , which reflects the ultimate rationality of a creator, underlying the superficial diversity of reality, i.e. the ideal of ultimate rationality . In other words, the goal of science has been to explain everything by reducing reality to a small number of general laws and principles, connected by a chain of logical deductions.
Reductionism is a philosophical position based on the idea that there is a connection between natural phenomena, reflected in the theories which study them. It states that a phenomenon can be redefined in terms of another, more basic or simpler one. In this context any system can be understood by breaking it down into component parts and studying the components in isolation. The totality of the complex is assumed to be the sum of its component parts.
Reductionist science is aiming at **total decomposition** of scientific objects into minimal units, or primitives . It aims at exhaustive decomposition into the simplest building blocks into which everything in the universe is decomposable.
Reductionism as epistemology means that science attempts to reduce the scientific body of knowledge of one discipline to another. For example, the properties and functions of life forms can be explained by reducing them to chemical compositions and ultimately, to atoms and particles.
Reductionism as methodology tries to define an entity in terms of smaller and simper units.
Reductionist scientific theories aim to explain a complex phenomenon with theoretical primitives, e.g. complex concepts are reduced to simple ones. Thus, complexity is reduced exhaustively to simplicity. Reductionism as a philosophy states that the only ontological reality is that of atoms and everything else is describable as their combinations. These foundational assumptions have been guiding principles for the most part of the history of science, i.e. science has aimed at uncovering the timeless simplicity of the immutable universe. During the Renaissance this world view was reflected in Newton's conceptualization of the universe as a machine, dominated by universal and eternal laws of motion.
Reductionism in scientific theories fits well with the mechanistic view of nature brought about by Newtonian physics which has been regarded as the golden standard in science for the

last few centuries.
And although over the centuries this method has been productive for accumulating knowledge of certain parts of reality, for example, the behaviour of large bodies of non-living matter, its dominance has been detrimental for understanding others, for example, minuscule bodies of matter, particles, as well as living organisms, not to mention their participation in larger units of organization, groups, families, and societies. In modern science Occam's advise for simplicity of explanation is taken to an extreme by modern minimalism, which aims at reduction of complex entities into simple ones by decomposing them into the most simple possible primitives. As an illustration, not only chemical substances, but organisms and even brains are reduced to atoms and even more elementary particles. The misuse of this scientific approach has resulted in misrepresentations of natural phenomena , in some cases, to the point of caricatures.
Kauffman in earlier publications identifies the complexity paradigm as reductionist.

" We seek reductionist explanations. Economic and social phenomena are to be explained in terms of human behaviour. In turn, that behaviour is to be explained in terms of biological processes, which, in turn are to be explained by chemical processes, and they, in turn by physical ones. " (Kauffman, 1995, p.11)

The reductionist approach has been criticized for being inadequate in contexts beyond physics. P.W. Anderson (1972) a professor of theoretical physics and Nobel Laureate writes "...The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe. In fact the more the elementary particle physics tells us about the nature of the fundamental laws, the less relevance they seem to have to the very real problems of the rest of science, much less to those of society. " (P.W. Anderson, 1972, p. 393-396). He further argues that new levels of complexity arise at different levels of organization making a complex entity not reducible to the collection of properties at the lowest level of complexity.

"... the whole becomes not only more but very different from the sum of its parts" (ibid. p. 395)

He criticizes attempts to reduce complex behaviour and especially human behaviour to laws of physics and chemistry , namely, "... to try to reduce everything about the human organism to "only " chemistry, from common cold and all mental disease to the religious instinct." (ibid. p. 396).
In more recent statements Kauffman focusses on philosophical implications of the chaos paradigm and advocates against the reductionist/physicalist mentality in modern society which appreciates pure rationality while disregarding the importance of values, ethics, spirituality and meaning. (Kauffman, 2006, www.Beyond Reductionism...edge.org).

" With reductionism comes the conviction that court proceedings to try a man for murder is " really" nothing but a movement of atoms, electrons and other particles in space, quantum and classical events, and ultimately to be explained, with, say, the string theory" (S. Kauffman, 2006)

Similarly, as per Prigogine and Stengers (1993, p.72-73) " Nature as an evolving, interactive multiplicity thus resisted its reduction to a timeless and universal scheme."
In sum, by the admission of prominent scholars, the reductionist approach has significant epistemic limitations.

5.2 Reductionism has cultural roots.

A slight deviation from the main topic I find interesting to entertain. Various scholars and philosophers have argued that the domination of reductionist views in modern society is biased by cultural prejudices and formalisms in science are biased opinions with which we approach nature. They are cultural products and as such represent cultural values and biases, reflected on thought, and by extension, scientific reasoning. This is the view of Michel Foucault, a respected philosopher, who, as paraphrased and referenced in Gould and Vrba, (1982) wrote : " ...when you know why people classify in a certain way, you understand how they think..."(ibid, p. 4). Thus, the way we label nature reflects our values as participants of a culture.

Nisbett and all. (2001) argue that logical reasoning is not universal either, it is culturally dependent. The widely held belief that basic processes of human cognition, e.g. categorization, learning, inductive and deductive inference and causal reasoning are innate , i.e. predetermined by human biology and as such universal and independent of culture, personal experience and/or training, prevalent in the western philosophical tradition, has been challenged. A comparative study of the Ancient Greek and Chinese cultures reveals that : 1. cognition is not universal, it is culturally sensitive, i.e. human cognition is determined to a significant extent by culture (thus, experience and learning). 2. Scientific thought reflects earlier stages of human cognition, , namely, mythic culture, and its conceptual models of the universe.

" The social – psychological aspects of Ancient Greek and Cheese life had correspondences in the systems of thought of the cultures. Their metaphysical believes were reflections of their social existences…These result in very great differences between Greece and China in their approaches to scientific, mathematic, and philosophical questions. " (Nisbett et all..2001, p.293)

The Chinese counterpart of the Greek sense of personal agency was a sense of reciprocity, of "social obligation or collective agency" (Nisbett et all., p.292).

" The cognitive differences between the ancient Greek and Chinese can be loosely grouped under the heading of holistic versus analytic thought. " (Nisbett et all. 2001, p. 293).

It appears that the ancient Greek and Chinese cultures have developed focus on different aspects of reality. Greeks see reality as a collection of individual objects, while Chinese, as members of a larger unity.

" A fundamental difference between the Chinese and the Greeks was that the Chinese held the view that the world is a collection of overlapping and interpenetrating stuffs, or substances…This contrasts with the traditional Platonic philosophical picture of objects which are understood as individuals or particulars " (Nisbett et all. 2001, p. 293).

And further, " One of the most remarkable characteristics of ancient Greeks … a sense of personal agency …The Chinese counterpart of the Greek sense of personal agency was a reciprocal sense of social obligation or collective agency. (Nisbett et all. 2001, p. 292) These cultural differences in world view have resulted in cognitive differences.

" We define holistic thought as involving an orientation to the context or field as a whole, including attention to relationships between a focal object and the field, and a preference for explaining and predicting events on the basis of such relationships. Holistic approaches rely on experience-based knowledge rather than on abstract logic and are dialectical, meaning that there is an emphasis on change, recognition of con tradition and of the need for multiple perspectives…We define analytic thought as involving detachment of the object from its context, the tendency to focus on attributes of the object to assign it to categories, and a preference for using rules about the categories…Inferences rest in part on the practice of decontextualizing structure from content, the use of formal logic, and avoidance of contradiction" (Nisbett et all. 2001, p.293)

The holistic nature of Chinese culture is reflected in their scientific methods, which focus on dialectics, constant change and mutual adjustment. The Greek preference for analytic thought has given rise to formal logic. In addition, Chinese acquire knowledge through experience, they " seek understanding through direct perception" (ibid., p.294). Greeks prefer abstract analysis. They build abstract models to understand natural phenomena and " were prepared to reject the evidence of the senses when it conflicted with reason" (ibid.,p.294)
So, the way scientific theories conceptualize the world is arbitrary, it is based on cultural conventions, and differences in the focus of study and the conceptual tools used for it reflect cultural biases. Interestingly, philosophical convictions and scientific arguments reflect biases of their proponents, whose minds are shaped by the limitations of their respective fields of inquiry. As per Kauffman (2006) " The physicists who hold out for firm reductionism are...high energy particle physicists..." In sum, there is no, and cannot be, pure reason.

5. 3. Biology against reductionism

The Chaos theory explains complex design in physical matter as perpetual alternation of order and disorder. It is recruited to explain complex design in life forms with perpetual alternation of speciation and extinction, adopting a reductionist approach by reducing living forms to inorganic matter.

That said, significant differences between the two ontological types put into question the epistemic value of the reductionist approach. In physics universal laws of matter which apply without exception are used, while in biology comparative methods are more informative and sweeping generalizations have only statistical value and exceptions are the norm. In this sense Mayr points out that changes in non-living matter and organisms are two qualitatively different processes. Transformations in matter produce unique entities from identical basic units, which places limits on possible combinations. The atom of iron remains unchanged irrespective of its participation in compounds or any external circumstances.

Organisms, on the other hand, are also unique, but their unique characteristics are at the molecular level, in the unique DNA and RNA, a product of historical processes under unique circumstances. They are open systems in which interaction with the environment is the essential property, not found in inorganic matter. The emerging properties of living matter are causally related to the fact that living organisms must adapt to changing environments in order to stay alive. Organisms are a different kind of matter and self-organization processes have different outcomes: the interacting entities, namely, biological bodies, become altered as a result of their interactions with one another within the group, between groups and with the physical environment.

In this sense Mayr (2001) proposes that unification of science (by finding common principles, methodology and terminology encompassing the study of both living organisms and non-living matter) cannot be achieved by reducing biology to physics. He argues that a unified science requires an extension of the concept of science which must include biology. Thus, he argues for a new synthesis, based on the concepts and methods of life sciences.
Similarly Lewontin (2002) argues convincingly against the suitability of reductionist approach to the study of living organisms.

" The problem for biology is that the model of physics, held up as the paradigm of science, is not applicable because the analogues of mass, velocity and distance do not exist for organisms "
(Lewontin, 2002, p. 93)

He defends a holistic approach stating that " there are no universal rules for cutting up organisms (ibid. p. 87) and also, that there are ".. quite different ways of cutting up an organism depending on what we are trying to explain" (ibid. p. 82). Further he explains that the methods of reducing natural forms to idealized types and studying them in isolation (vacuum) used by the so called "hard sciences " are inadequate for studying organisms which have irregular shapes and , unlike physical substances, do not exist passively in isolation, but interact with the external world, affect it and are affected by it.
Johnson and Lam (2010) explain that in inorganic context "a self-organizing mechanism in isolation is an intrinsic property, a purely spontaneous process, that is , a product of given circumstances" (ibid. p. 882). Self-organization processes in biological context require conditions to be continuously sustained. Thus, in inorganic context self-organization is an event, while in biological context it is a process. And, crucially, " selection has to fine-tune and control many parameters to get work out of a self-organization process" (ibid. p. 882)
Thus, organisms and inorganic matter are qualitatively different parts of nature and so are the mechanisms intrinsic to them. Self-organization does occur in biological forms, but only in the context of evolution.

5.3.1. Universal law of change at the edge of chaos?

" These patterns of speciations and extinctions, avalanching across ecosystems and time, are somehow self-organized, somehow collective emergent phenomena, somehow natural expression of the law of complexity we seek... from ecosystems to economic systems undergoing technological evolution ..from single cells to economies ...evolve to a natural state between order and chaos.(S. Kauffman, 1995, p. 10).

Kauffman argues for a universal law of change as he detects similarities in the patterns of change in the physical, biological and cultural systems, i.e. complex design in all ontological contexts happens at the edge of order and chaos. For example, technological evolution proceeds in terms of successive stages of creative exuberance of multiple technological innovations, which are selectively adopted under market demands for efficiency and affordability.
To sum up with the artfully articulated conclusion of Kauffman " Tissues and terracotta may indeed evolve in similar ways. General laws may govern the evolution of complex entities, whether they are works of nature or works of man." (Kauffman, ibid. p.113).

Does this imply bridging the divide of mind and matter?
Heylighen (2013) argues that the results of spontaneous interactions in the physical systems are indistinguishable in their final results from goal-oriented action directed by a conscious mind. Actions, both intended by the mind, or automatic, as in physical matter, are indistinguishable as long as they produce irreversible results. This is the common denominator of matter and mind.

"...the complex systems approach transcends the mind-matter duality: causal (material) and intentional (mental) models are essentially equivalent, even though one may be more easily applicable in certain contexts than the other (ibid., p.3).

Here I can only raise the question and leave the discussion to scholars with relevant expertise.

6. Complex Adaptive Systems (CAS)

Complex Adaptive Systems were initially defined as physical systems, dynamic in nature, formed by the coordinated interactions of subsystems, each individually organized and functioning as integrated and interconnected components of a larger system . A CAS is formed and functions under the complexity principles by the contributions of individual participants with their interactions at a local level following simple rules. It is adaptive if it is able to maintain its internal organization while at the same time adapting to changes imposed from outside (Heylighen 1999).
The CAS perspective was originally designed for understanding complex integrated phenomena in inorganic matter and later was adopted as a universal law of change in all ontological contexts, while applying the theoretical machinery designed for studying physical matter, i.e. an example of theoretical reductionism.
In biological context CAS are complex integrated associations of biological entities which adapt to one another forming ecosystems , both in flora and in fauna, and change in concert in adapting to a common physical environment. For example, predator and pray coevolve as part of a niche. In fact the boundaries between individual evolving entity and the environment is blurred (Kaufmann, 1993; Lewontin 2002).
Behaviour, morphology, metabolism of a biological body coevolve as a CAS. Mutual adaptation among systems and organs within a biological body is encapsulated in the term " exaptation", a process by which a biological entity, either with a purely supportive function, i.e. a spandrel, or with established function, i.e. preadaptation , undergoes modification of its internal organization as adaptation for a new function, while, often maintaining the original one as well. Exaptation is nature's answer to the demands of sudden change in the environment, often initiating a process of speciation. A classic example of exaptation in the bird feathers, initially an adaptation for insulation, e.g. archaeopteryx had feathers although it could barely fly. More exampled can be found in Gould and Vrba 1982, p.7). So, exaptation is actually a version of adaptation. Clearly, initially the new function is made possible with machinery not specified for it and the best possible scenario is when the old and the new functions are as similar as possible as demands for modification would be minimal and the period of transition shorter.
Importantly, sudden alterations usually concern simple organisms, e.g. bacteria, while complex

organisms with numerous interwoven components do not reorganize in a single event. Mutations triggering significant with organism-transforming consequences are usually deleterious. The primate brain cannot be expected to have become human in a single event. In short, as per Kauffman (1995) CAS illustrate " evolution of coevolution" at the edge of order and chaos.
Significantly, coordination in evolutionary processes in various contexts and timeframes is argued by some proponents of the Darwinian approach who view biological evolution, especially in complex organisms, to be a coordination and mutual adaptation in the genome, the phenotype, developmental patterns and behaviour (Jablonka, Lamb, 2006).

The CAS paradigm demonstrates the value of theoretical integration in understanding complex phenomena. In this sense the view of language as a CAS where multiple systems, biological, cultural, cognitive , etc. each explicable by different formalisms, interact and integrate in the formation of language. The evolution of language as a complex phenomenon is defined in terms of CAS as " complex interplay of influences of different kinds (each described, imperfectly by their unique formalisms)" (Heylighen, 1999, p.70).

In biological systems the coordinated changes in the components of CAS can be defined as "co-evolution". Encyclopedia Britannica defines co-evolution as a a process of " reciprocal evolutionary change" which occurs in entities (species, groups of species) as a result of their interaction and interdependence. The same process of mutual adjustment based on co-dependence is proven to be at work between organs and systems within an organism as well as between biological/cognitive entities and behaviours. In both cases the co-evolving entities form part of each other's environment as a case of mutual adaptation. A typical example is an eco-system where multiple species co-exist and co-evolve with one another and the physical environment. In the context of the CAS theory every participant in an eco-system exists at the edge of order and chaos and, consequently, the eco-system as a whole is permanently placed at the edge of order and chaos.

6.1. Irrelevance of the debate on gradualism vs. catastrophism?

In the theory of evolution in all its interpretations the evolutionary process is defined by two fundamental and distinguishing characteristics: it is series of successive small genetic innovations each judged by their functionality. Its theoretical alternative in understanding and explaining the causes of diversity of life forms is the Gouldian view which explains the diversity of species as alternation between protracted periods of stability, interrupted by sudden bursts of biological creativity, articulated in the hypothesis of Punctuated Equilibria (Gould, Eldridge, 1972). The empirical support for either is limited to certain species and certain periods. For example, there is clear evidence for the gradual evolution from dinosaurs to avian species with an intermediate species of archaeopteryx. On the other hand, the gradualist argument is been questioned as fossil records of various species fail to show an unbroken chain of continuous intermediate stages, interpreted by some as a demonstration of discontinuity. A plausible explanation for such gaps is that each of the two sources of biological innovation works in different circumstances , e.g. gradual, slow adaptive changes occur in large populations, while relatively rapid, abrupt jumps with peaks in activity, which disturb the usual stability, happen in small, isolated populations.

At the same time Joseph and Janda (2003) find the debate on gradualism vs. saltationism irrelevant, arguing that each of these alternatives explain the same facts from different viewpoints involving different time-scales, i.e. geological (where time is measured in millennia) and biological (which measures changes in a few generations). The argument is that on a geological scale gradual changes, which are normally small and cumulative , are undetectable and thus, are registered as stasis. Changes are registered only when the difference of before and after is significant enough to be detectable, which explains the apparent gaps in the material remains they have left behind in the paleontological record. Small events of little significance which bring quantitative alterations, each building on the next, sooner or later result in qualitative transformations. Thus, small changes are only noticed when they accumulate and produce evolutionary Rubicons as quantity transitions into quality. In this sense it is not easy to differentiate between evolution and self-organization as the cause of a transition observed in the record.
And for an organism the sources of variation, e.g. imperfect copying, as envisioned by the theory of evolution, or sudden jumps in creativity, as in the theory of complexity, are irrelevant . The causes of variation (genetic accidents) or spontaneous interactions (resulting in self-organization of some kind) are also unimportant. All that matters for the biological form is to survive in the current environment.
The same applies to social contexts, e.g. scientific and technological advances are made some times by accident, i.e. novelties are formed bottom-up, and some times by the direction and financing of a government, i.e. under centralized control.
From a different perspective, selection is a component of the evolutionary process where improvement is produced by selectively multiplying variants produced by copying errors. Positive feedback loop is a component of self-organization process where improvement is produced by selectively perpetuating patterns by amplified repetition. Thus, feedback loop and selection have very similar functions, i.e reducing randomness by selective perpetuation.
Thus, despite the fundamental differences in these two processes, outlined in earlier segments, there are also commonalities: some novelty or improvement is created by selective repetition of some among multiple available options.
From a different angle, evolution is usually defined as a blind process, i.e. without any intended direction, while self-organization is viewed as goal-oriented towards equilibrium. Yet in evolution only the formation of variation is blind, while selection has a clearly defined goal, the survival of the species. In this sense the difference between evolution and self-organization is not easy to discern.

7. Complexity paradigm in linguistics

The complexity paradigm is used in linguistics in two contexts. On the one hand, it is applied by the generative/biolinguistic perspective which understands the formation of a language faculty, or Universal Grammar in terms of spontaneous self-organization and formation of stable neuronal networks for processing language. On the other, for understanding the formation of individual language systems from communicative interactions among language speakers as community members.

7. 1. Physicalist perspective, minimalism and the language faculty

The generative paradigm and especially its most recent version, the Minimalist approach has as its goal to uncover the principles of linguistic computation , under the tacit assumption that the generative component of the language faculty is defined by utmost simplicity and generality of computation mechanisms, found in inorganic matter. The Minimalist perspective is in unison with Kauffman's view's of laws of life, as he suggests that formal theories must focus on reducing theoretical complexity by focusing on fundamental and universal properties of life forms, while delegate the details to development to fill in (Kauffman 1995, p.10-11). This position reflected in the Principles and Parameters approach (Chomsky, Lasnik 1993 and elsewhere), where the defining properties of the language faculty are termed universal principles, permanently configured in the brain architecture, the details are in the form of underspecified binary options, or parameters. And although parameter choices are said to require some experience with a language, overall the role of the environment is limited as the internal organization of the language faculty is said to be largely endogenous. The core computational operation Merge operates in cycles and builds increasingly more complex hierarchies ad infinitum. In this way the crucial component of the language faculty is understood as instantiation of maximally generalized universal principles of structure formation, reminiscent of the universal principles of pattern formation in physical matter, outlined in the sciences of complexity. The most resent proposal by Chomsky (2005) outlines three components in the formation of the language faculty: **1**. genetically predetermined language-exclusive bio-computations , **2**. general cognitive capacities applied for language-relevant functions , e.g. , speech production, theory of mind, memory, etc. and **3**. general principles and conditions of efficient structure-formation underlying all physical nature, referred to as “ the third factor”. This informs his rejection of Darwinian explanation for the language faculty and shapes his argument for the influence of physical forces which, in his mind, explains the perfection of this hypothetical grammar- computing cognitive entity. So, the appearance of the language faculty here is explicable by principles of physics, not biology and as such, is immune from evolutionary explanation. The vision that laws of physical nature influence the shape of language is consistent with the guidelines of the reductionist approach in classical science.

Importantly, the application of complexity principles in the context of language reveals an inherent contradiction with the computational approach as complex systems and algorithms are based on different mechanisms. Computation works like LEGO, i.e. primitives are assembled into a structure following rules and the product is exhaustively decomposable into primitives. The language algorithm produces a sentence with one meaning as a sum total of the literal meanings of the component linguistic forms and their position in the hierarchy, i.e. 2+2=4. On the other hand, evolutionary processes will inevitably be implicated in the existence of any biological entity, with or without some form of participation of self-organization, and, as per Kauffman (2006) evolution in biosphere is not algorithmic or digital. Thus, the framing of a language faculty, a biological entity, in therms of digital computations is self-contradictory.

If language is viewed as a communicative technology from a complexity perspective a sentence is an integrated whole with holistic properties, irreducible to the sum of its components, e.g. in holistic expressions, e.g. “ when pigs fly” and where the added value comes form the contribution of context. e.g. rhetorical questions, interpretation of negative sentences as affirmative in irony, etc. i.e. 2+2=5.

The contradictions do not end here as the language faculty is argued to display similarities with any other biological organ in the human organism, while at the same time displaying properties highly unusual for a biological form as a biological form with exceptional properties, e.g. unlimited recursion, perfection, i.e., properties foreign even to machines (Chomsky 2000, 2005, 2006, Hauser et all. 2002 and elsewhere), in effect undermining the innatist argument. None of the postulated properties are proven or provable and the argument for discontinuity, stemming from that, contradicts well-known fact that the human brain shares many similarities with the ape brain. Crucially, Broca's area, argued to be the language faculty, has a homologue in the ape's area F51. So, Broca's area is not a biological innovation. Moreover, although the human brain displays some differences from the ape brain, these do not constitute any evidence of complete architectural transformation , which one might expect to result from the spontaneous emergence of a completely new kind of structure. P. Liebermann, discusses in detail the overwhelming evidence for continuity in the brain architecture and functions of the human brain and argues that although language is a novel and unique behaviour, it is made possible by the human brain as a slightly modified reptilian brain (Liebermann, 2001) .
In addition, Gary Marcus (2008) argues that not only the human mind is a kluge, that is, far from perfect, though good enough and useful cognitive organ, but the language capacity is a kluge as all natural languages are highly imperfect, with abundant redundancies and imperfections. Moreover, he argues that humans are unable to learn artificial languages intentionally designed to avoid the imperfections of natural languages.

In sum, the theoretical models of the language faculty, proposed by the mainstream generative/biolonguistic approach are borrowed from physics and attribute properties of physical matter to hypothetical biological formations. Chomsky famously stated (2002 and elsewhere) that the abstract models reveal the truth while observable phenomena are a distortion of the truth. He even has encouraged life sciences to replace biological forms with idealizations in search of reliable understanding.

That said, although abstractions are a legitimate and highly useful tool in any line of inquiry, they must reflect the most distinct properties of the object at hand. In life sciences are prototypes or the best examples as representative of species or populations, routinely used in lab experiments, vaccine testing, etc. If linguistics is defined as natural science and the language faculty as a biological property, these deviations from the established practices are inexplicable.

7.2. Language faculty emergent by learning

Self-organization is evoked as explanation for developmental patterns not pre-specified by genes but emergent during epigenesis (Waddington 1953; Dor , Jablonka 2000). Emergent developmental routines are termed “canalization”. For some this involves the formation of neuronal connections in the infant brain and their stabilization as neuronal pathways supporting behaviours, e.g. in connectionist models , where some emergent neuronal patterns are selectively solidified thanks to positive feedback, while others disappear due to negative feedback. An emergentist perspective in linguistics explains the formation of a language faculty in the adult language user using connectionist models(Ellis, 1998).
For others a language faculty is formed in the adult mind by coordination of a multitude of

cognitive modules supporting general cognitive behaviours, jointly used in various activities not specific to linguistic behaviour (Donald 1993, Studard-Kennedy, Knight, Hurford, 1998) which participate and interact in the process of language use.
Similarly Corning (1999) talks about language capacity in terms of a synergistic effect as cooperative behaviour achieved by coordination among various cognitive and physiological activities in the individual mind as well as in coordination with the minds of fellow communicators, all influencing the formation of an idiolect, i.e. a person's individual I-language. The emergence of language in the individual presupposes synergistic activities at multiple levels.

A. synergy among organs and systems in the individual organism:

a. synergy among the articulatory organs for the purpose of speech production

b. synergy among cognitive capacities, e.g. capacity for reference (to represent a class of objects through signs (as special case symbolic thought, symbolic representation), capacity to form categories, capacity for mind-reading, or theory of mind, capacity for self-monitoring, or metacognition, consciousness (awareness that one's person and mind differ from others), intentionality (stimulus-free initiation), capacity to learn , extended memory, planning, imagination (or displacement: capacity to refer to referents, distant from here and now), capacity for socialization (need for the company of conspecifics)

B. cognitive and behavioural synergies among the members of a group, e.g. synergy in behaviours resulting in common cultural practices (symbolic and practical) , synergy in conceptualization resulting in the so called " common ground' , a standardized view of reality reflected in myths, folklore, etc. which makes possible the formation of a vocabulary.

In short, language processing requires the coordination not only of organs and systems of the individual organism, but coordination of multiple organisms.

That said, the transplant of theoretical tools originally designed for understanding physical matter into linguistics for understanding the individual and social aspects of language has its limitations. Atoms and molecules, the interacting agents in physical matter, are identical and eternal and their interactions are determined by universal principles of matter. On the other hand, the formation of the idiolect by self-organization in neurons is not an event but a protracted process highly influenced by variations in genetic, epigenetic, developmental, experiential, etc. factors, all influencing the formation of idiolects in different ways. Moreover, today language learning is guided by schooling which reduces randomness and introduces central control in the formation of idiolects, i.e. reducing the role of self-organization and challenging the emergentist argument for order from below. Thus, the formation of complex design in chemical elements, atoms and molecules is fundamentally different from language learning.

In sum, while the formation of clouds and hurricanes, fish shoaling , wall building by ants, the synchronized flashing in fireflies (Camazine et all. 2003) are credibly explained with the principles of self-organization, the formation of a language processor in the human brain is a multifactorial process and demands diverse theoretical instruments.

7.3. The language system, a complexity perspective

From a complexity perspective the language system is understood as a novel ,complex entity, emergent from the interaction of multiple subcomponents or subsystems. The complexity of the

system increases with each higher level as each level adds new types of interactions and each subsequent level contains the complexity of lower levels and builds on them.
Ellis(2011) and also Ellis, Larsen-Freeman (2009) (position paper)outline the main characteristics of language from the complexity perspective :
a. Complex systems in nature and human behaviour in general lack a controlling centre and are formed as global patterns emerge from local interactions without predetermined outcome, e.g, hurricanes, bird flocks and supermarket lines. In this context the language system is viewed as a novelty and grammar is understood as unpredictable patterns, emergent spontaneously from the communicative interactions of speakers .
b. Complex systems are by nature unique. In thus sense each language speaker is a unique individual , a speaker of an idiolect, a unique version of the language system. Each idiolect is a unique result of the individual's experience with the world and other idiolects. There is no one prototypical speaker or a prototypical community.
c. Complex systems are dynamic, in constant flux as they are in perpetual search for equilibrium between the demands of speakers and listeners, production and comprehension. Both the idiolects and sociolects are dynamic systems, constantly reorganizing.
d. From interactions patterns arise and become perpetuated through positive feedback, that is, each pattern repetition encourages further repetition, or alternatively fades away due to negative feedback. Language as an abstract system is understood as emergent through experience from the social interaction with conspecifics.
e. In complex systems small local changes can have dramatic global effects, or phase transitions, known in the complexity theory as “ butterfly effect”, recruited to explain sudden emergence of novelties in both biology and culture. For example, it is argued that abrupt changes in small sections of the genome in the Homo lineage have produced the Homo sapient species with qualitatively different characteristics, a pattern noticed in language learning when children experience sudden dramatic increase in vocabulary, also known as lexical spurs , leading to the emergence of grammar.
f. In a complex system the interactions are localized as each individual entity has access and interacts with a limited number of neighbouring entities. By the same token an individual speaker communicates with a small social circle of friends and relatives who form a network and influence each other's idiolects .This maintains the individuality of idiolects which feeds language change.
The language system as abstraction is represented by the commonalities in idiolects. And in the formation of the language system two different but interrelated levels of self-organization are at play: one at the level of the individual organism, its mind and individual experiences , which gives rise to the idiolect, and the other, at the level of multiple individual minds, which gives rise to the sociolect.
Similarly, Keller (1994) presents the ' invisible hand' hypothesis where a sociolect emerges spontaneously as unintended byproduct of the rational and intentional interactions of individual speakers to communicate with conspecifics in an attempt to solve interpersonal problems at a local level. Thus, language as patterns in the brain and in social behaviour, is the result of human actions but not the intended result.
To note, it is universally acknowledged that language is a complex entity, but the very definition of complexity in linguistics is far from agreed upon. Some understand complexity of a system as lack of order, others identify a complex system as one positioned at the edge of

order and chaos (Gell-Mann 1992). Mufwene (2014) views language " in constant state of flux, in search of equilibrium".

In short, although in this context the sociolect is formed by random interactions of idiolects, linguistic innovations introduced by individuals with high social status and power will be selectively imitated and perpetuated, thus, injecting influence of central control.
Thus, self-organization alone cannot explain all aspects of language formation.

7. 3.1. Languages as unique emergent systems

Chater and Christiansen (2008) explain language diversity as different languages being, to paraphrase, different local solutions to a combination of constraints imposed by cognitive pressures and cultural and historical idiosyncrasies. As the local cultural and historical factors vary across communities, languages find diverse ways to achieve the right balance mediating these pressures differently at different time periods. Similarly, Evans and Levinson (2009) identify language diversity as a language universal and explain observable recurrent patterns of organization in languages as "stable engineering solutions satisfying multiple design constraints, reflecting both cultural-historical factors and the constraints of human cognition"(ibid. Abstract). In this context linguistic categories are language -particular generalizations resulting from convergent patterns of language use based on universal semantic categories. In a similar vain Haspelmath (2007) underscores that grammatical categories are language-particular, e.g. languages with apparent structural similarities, e.g. German and Russian, show clear differences in the category of dative case, there is diversity in the category of Adjective. Even categories like " word" and " sentence" appear to be language-particular. Importantly, not only grammatical systems but also semantics is language-particular as " the same fact or event is not only expressed differently, but also structured semantically in a different way , in different languages" (Zaefferer,1991,p. 46).

From evolutionary perspective information on the origin of the first sociolects can be extrapolated from emergence of a language system from scratch observed today. For example through computer simulations it is demonstrated that artificial agents, through coordinated interactions, converge onto a unified symbolic system (Dale Barr, 2004; Steels,1995). Similar experiments simulate the emergence of discrete speech sounds where through the actions of artificial agents mimicking human individuals it is demonstrated that discrete reusable units of speech, phonemes and syllables, emerge as crystallized point along a sound continuum under the pressures of ease of articulation and auditory distinctiveness (Oudeyer 2006; also Bart de Boer 1998). For a compact review see B. de Boer 2005.

Jill Morford (2002, p.338) has documented the formation of homesigns, i.e. unique cases of formation of language systems in gestural domain by individuals with abnormal ontogenetic experience, deprived from normal access to spoken language , who invent a form of gestural language system. This informs an extrapolation that a similar process of self-organization could have taken place in the first stages of language origins.

In addition, Studderd-Kennedy (1998) discusses a general principle of particulation , known as " particulate principle of self-diversifying systems" as coined by W. Adler, by which holistic entities are broken down into discrete components which are then combinable. The particulate principle explains the formation of discrete primitives, combinable into hierarchical systems, e.g. chemical compounds, the genetic code. Particulation is viewed as part of self-organization as a general process of nature, which in evolutionary linguistics explains the formation of phonetic gestures and the generative phonology out of holistic vocalizations, opening the way to the formation of multileveled linguistic structure.

The Chaos theory has a place in evolutionary linguistics both in bio-linguistic context for explaining the formation of the individual language faculty and the idiolect, and the sociolinguistic aspect for explaining language diversity. That said, as argued in previous segments, the language-relevant innate predispositions of the human individual and its implementation in linguistic behaviour are better explained with the theoretical instruments of the evolutionary theory. Thus, evolutionary linguistics would be better served by enriching its theoretical instrumentarium with elements of both.

7.4. The language faculty: self-organization+evolution

Chomsky and some of his followers have adopted the Gould/Lewontin's argument as they attribute the existence of Narrow Language Faculty(FLN), i.e. the computational component, to a unique event of self-organization and the Broad Language Faculty(FLB), i.e. the realization of grammatical computations in communication, to a process of evolution, given the fundamental differences in their functionality as articulated in (Hauser et all. (2002) Chomsky (2005) and elsewhere.

An evolutionary process implies continuity. The evolution of the FLB is said to be a long and protracted process of gradual improvement in a number of cognitive, anatomical and physiological traits in ancestral species, which in combination allow the formation and use of a protolanguage, a rudimentary communication system, attributed to pre-humanHomo species(Bickerton 1984 and elsewhere). The crucial innovation, the essence of human speciation is envisioned here from an evolutionary accident , a result of self-organization within the human brain, producing UG component, as the two cognitive entities, different in function, become connected and integrated in a new bio-cognitive entity. Thus FLN becomes an add-on to FLB. In short, representation of language in the human body is understood in terms of applications of two very different natural laws operating in succession, i.e. products of self-organization are added to products of evolution.

8. CAS :integrating the theory of evolution and the Chaos theory in understanding the evolution of human language

To remind, the CAS perspective is originally designed for understanding complex phenomena in inorganic matter as integration of self-organization processes. Given that it reflects the properties of inorganic matter , in my mind, has significant explanatory limitations for understanding the human organism, mind, and language, as well as language evolution, phenomena hardly explicable by simple processes in simple units of matter. Its interpretation in biological contexts as co-evolution promotes the understanding of coordination in biological processes, adding a time dimension to the already complex interactions in space, as articulated by the Chaos theory.

The adoption of the Complex Adaptive Systems framework in evolutionary linguistics as coordination of processes and contexts highlights some crucial aspects of language evolution as a multifaceted process of coordinated adaptations in diverse contexts at multiple levels and time frames, in terms of co-evolution as coordination of three types of evolutionary processes , i.e the human genome, learning mechanisms and cultural practices, adding additional levels of complexity.

8.1. Eco-evo-devo: the co-evolution of genomic processes, human development and glossogenesis within a socio-cultural niche

Species inhabit specific facets of the environment, i.e. environmental niches, where they exist and function, which inevitably leads to mutual adaptation between the two. Some species live in water, others inhabit mountain terrains of high altitude where oxygen is scarce .

An environmental niche for humans includes the artificial environment constructed by invention and dissemination of cultural products, e.g. ideas, artifacts and practices, which interact and co-evolve with the human organism by mutual adaptation and reciprocal causation (Richerson, Boyd, 2005 and elsewhere; Laland et all. 2012; O'Brien, Laland 2012).

In tis context language is formed within a human niche by coordination and and interdependence of a variety of factors , e.g. language processing and language learning , the human experience with the world through the senses, human cognition and its species-specific ways of interpreting this experience, human interaction with conspecifics, culture, human history, all of which interact.

The recognition of the interaction and interdependence of nature and nurture, biology and culture, and the role of human development as a mediator of this process, advocated by the EES, is gaining influence among students of language evolution. This integrative approach does not postulate biological inheritance of linguistic features, only the ability to anticipate, learn and process such features, ability resulting from the integration of genomic and epigenetic processes, learning mechanisms and the socio-cultural environment incorporating social structures and cultural conventions (Segovia-Martin, Balari 2020), i.e. the evolution of language is understood in the context of a human bio-cultural niche, constructed out of co-dependence and co-evolution of three inheritance pathways : genes, language learning during human development and culture.

At the same time the individual sub-systems of the human niche have their own individualities reflected in differences in internal properties, their organization and trajectories of change. And although different schools of thought offer alternative explanations, framing the internal dynamics of of change by evoking either evolution or complexity theory as theoretical frames, some aspects of the interactions within the human niche are better explicable with evolutionary principles, while for others the complexity theory seems a better fit. For example the co-evolution of the brain and its functions, including language-relevant functions, is a protracted and incremental process which resulted in mutual alteration of each as increased cognitive functions demanded a substantial increase in absolute brain size. This in turn made possible further increase in cognitive capacities, a crucial contribution to the evolutionary success of our species over other homo species by developing complex culture, language and civilization. So, on the one hand alterations in the physical properties of the brain have facilitated the elevated cognitive abilities. On the other the increased cognitive capacities necessitated higher energy which imposed higher nutritional demands to the human organism. This, in turn, triggered

evolution in the lifestyle of the homo sapient species, manifested in the increased consumption of meat, resulting in " arms race " between human biological body and cognition. So, the mutual adaptation of biology and cognition is better understood within the conceptual frame of the theory of evolution.
Similarly, co-evolution between the human speech capacities and elevated cognitive capacities demonstrated by extended human semiosis is the advanced articulatory dexterity in the articulation of the quantal vowels /i,a,u/ resulting in the ability to learn and retain a large lexicon(Liebermann, 2006 and elsewhere). In addition, co-evolution of human development and language as a behaviour resulted in a human developmental instinct for babbling.

" The disposition to babble is thus adaptive in a social group that already benefits from communication in speech. It seems likely that a capacity for finer tuning of the articulators and more precise coordination of their interaction evolved biologically as the benefits of well articulated speech emerged. This would have been a case of gene-culture, more specifically gene-language co-evolution." (Hurford, 2011, p. 488),

These are also bio-cognitive processes, extended in time and progressing in incremental stages, unlikely to fit the theoretical frame of the complexity theory where change is viewed as an event.
On the other hand Schoenemann (1999, 2005) finds the complexity theory better fitted for explaining syntax as a solution to a bottleneck formed by the cognitive capacity to conceptualize in exquisite detail the world and the limitations of human physiology to communicate this rich content with limited physiological resources under the time restrictions of a conversation. For others grammar emerges from the discrepancy between the enormous size of language and the processing limitations of the human brain, (Christiansen, Chater 2008). Grammatical rules and categories emerge as a solution to this inadequacy. Yet others explain compositionality and grammar as emergent through iterated language attainment by youngsters as every new generation adapts the language system to the limitations of the young brain by introducing new regularities given that regular patterns are preferred by learners (Kirby, 1998; Smith, Kirby, Brighton 2003).
Givon (1979, 2002) argues that complex grammar emerges as a result of extending the spheres of language use from the limitations of the immediate circle of communicators to a larger and more informationally diverse society. In this context change of function triggers a demand for transformation in the language system in terms of transition from loosely connected utterances and meaning-based linguistic communication in a "society of intimates" into a tightly organized system of sentences with highly regularized syntactic structure. Thus, social changes trigger behavioural changes resulting in change in language functions and, consequently, in the language system. And although the principles of selection are evoked in the coordination of social relations, language and cognition and within the components of language, i.e. meaning, structure and form as a communicative technology by some scholars (Steels 2011) these are better understood in terms of a succession of events proliferating from the bottom-up, rather than directed from an authority. Moreover, it is known from historical linguistics that transformations in language systems happen much faster, i.e. in a matter of decades, while bio-cognitive processes take multiple millennia to unfold.
In short, some aspects of language evolution are better explicable with self-organization, e.g.

emergence and proliferation of a new linguistic form in terminology, a new expression, etc. Even entire language systems have emerged in a very short time, e.g. sign languages. Others, e.g. internalization of some aspects of language is dominated by Darwinian processes. In this sense one may define complex entities and language as “ the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its properties”. Schoenemann (2017p.70)

Summary and conclusions

The theory of evolution and the Chaos theory explain complex design in two very different ontological spheres. The Chaos theory explain complex design in physical mater in terms of perpetual alteration of order and disorder. In this context the term Complex Adaptive Systems (CAS) the formation of complex design in physical matter is explained with the perpetual alternation of order and disorder in multiple physical systems with mutually coordinated and synchronized behaviours.
The theory of evolution explains complex design in life forms in terms of perpetual adaptation to the environment for preservation of life. The Chaos theory is also evoked as alternative explanation for complex design in life forms in terms of alternation of stasis and flux, stability and spontaneous emergence of novelty. CAS theory is evoked to explain complex design in life forms with interaction of self-organization and selection as “ mutual embrace of spontaneous order and selection's crafting of that order” (Kauffman, 1995, chap. 1 p. 6)
Language is a highly unusual entity: it is a multifaceted, heterogeneous phenomenon : its components represent all ontological categories: from physical matter (sound waves, atoms and molecules in the human body), to biological material (organs, tissues and neurons), to abstract concepts. No wander explaining its existence has proven to be a challenge for humanity since the beginning of history.
It is a truism that it is a challenge for any one formalism to explain reality in all its facets. This is particularly applicable to language. This is why an integration of the two theoretical perspectives promises to offer a much better understanding of the events and processes which lead to its current form.

References

Anderson P. (1972) More is different, Science, 177, p. 393-396
Barr D. (2004) Establishing conventional Communication systems. Is common knowledge necessary? Cognitive Science, p.937- 962
Batten D., Stanley S., Boschetti F.(2008) Visions of evolution: self-organization proposes what natural selection disposes, Biological theory 3(1), doi: 10.1162.biot.2008.3.1.17
Bickerton D. (1984) The Language Bioprogram Hypothesis, BBS, 7 , p. 173-221
de Boer B.(1998) Emergence of sound systems through self-organization, www.ai.rug.nl/~bart/naic98.pdf
de Boer B. (2005) Self-organization in language, doi: 10.1017/CB09780511542275.009
de Boer B. (2011) Self-organization and language evolution, in Gibson, K. , Tallerman, M. Eds. Oxford Handbook of language evolution, Oxford University Press, p. 612-620
Calvin W., Bickerton D.(2000) Lingua ex machina, Reconciling Darwin and Chomsky with

the human brain, MIT Press
Camazine S.(2001) Why self-organization, in Camazine et all. eds. Self-organization in biological systems ,Chap.5, Princeton Univ. Press
Carstairs - McCarthy A. (1999) The Origins of Complex Language: An Inquiry into Evolutionary Beginnings of Sentences, Syllables and Truth, Oxford Univ. Press
Chater N., Christiansen M. (2008) Language as shaped by the brain, Behaviour and brain sciences, 31, p.489-558
Chomsky N.(2000) New horizons in the study of language and mind, Cambridge Univ. Press,
Chomsky N. (2002) On nature and language, Cambridge Univ. Press
Chomsky N.(2005) Three Factors in Language Design, Linguistic Inquiry, Vol. 36, No.1, 1-22, MIT
Chomsky N.(2006) Language and mind, MIT
Chomsky N., Lasnik H. (1993) Principles and Parameters theory, in Syntax: an international handbook of contemporary research, Berlin, De Gruyter
Corning P. (1998) The synergism hypothesis, On the Concept of Synergy and It's Role in the Evolution of Complex Systems, in Journal of Social and Evolutionary Systems, 21(2), p. 133-172
Corning P. (2002) Re-emergence of emergence, a venerable concept in search of a theory, Complexity, 7(6), p. 18-30
Dawkins R. (1976) The Selfish Gene, Oxford University Press
Dor D.; Jablonka E. (2000) From cultural selection to genetic selection, Selection, 1-3, p.33-55
Edelman J.B., Denton, M.J. (2007)The uniqueness of biological self-organization, challenging the Darwinian paradigm, Biol. Philos. 22, p. 579-601
Ellis N. (1998) Emergentism, connectionism and language learning, in Language learning, 48:4, p. 631-664
Evans N., Levinson, S.(2009) The Myth of Language Universals : Language Diversity and its Importance for Cognitive Science, Behaviour and Brain Sciences, 32, p. 429-492
Fitch T. (2010) The evolution of language, Cambridge University Press
Gell-Mann M.(1992) Complexity and complex adaptive systems, in Hawkins, J., Gell-Mann, M. The evolution of human languages, Proceedings of the workshop on the evolution of human languages, 1989, Santa Fe, New Mexico, Addison-Wesley Publishing, p. 3-19

Givon T, (1979) On Understanding Grammar, Academic Press
Givon T. (2002) Bio-linguistics, the Santa Barbara lectures, John Benjamins
Gould S, J.; Eldbridge N. (1972) Punctuated equilibria, alternative to phyletic gradualism, in Schopf, Thomas, Freeman,eds. Models in paleobiology, Cooper and Co.Publishing, San Francisco, p.82-115
Gould S.J., Lewontin, R.(1979) The Spandrels of San Marco and the Panglossian Paradigm: a Critique of the Adaptationist Programme, Proceedings from the Royal Society of London, Series B. Vol 205, No .1161, p. 581-598
Gould S.J., Vrba E.(1982) Exaptation, a missing term in the science of form, Paleobiology, Vol.8, no.1, p. 4-15
Haspelmath M. (2007) Pre-established categories don't exist, consequences for language description and typology, Linguistic typology, 11 (1), p.119-132,

doi:10.1515/LINGTY.2007.011
Hauser M. , Chomsky N. Fitch, T. (2002) The Faculty of Language, What is it, Who Has it, How did it Evolve, Science 298, p.1569-1579
Heylighen F. (1999) The science of self-organization and adaptivity, The Encyclopedia of Life Support Systems 5(3), 253-280
Heylighen F. (2008) Complexity and self-organization, in Bates, M.; Maack, M., Encyclopedia of library and information sciences, Taylor and Francis
Heylighen F. (2013) Self-organization in communicating groups, the emergence of coordination, shared reference and collective intelligence, doi: 10.1007/978-3-642-32817_10
Hull D. (1988) Science as Process, An evolutionary account of Social and conceptual development of science, University of Chicago Press
Hurford, J. (2011) Linguistics from evolutionary point of view , in R. Kempson, T. Fernando, N. Asher, eds. Handbook of the philosophy of science, vol. 14, Philosophy of linguistics, p. 473-498, Elsevier,
or www.lei.edu.ac.uk/~jim/handbook.phil.ling.pdf)
Jablonka E., Lamb M. (2005) Evolution in Four Dimensions , MIT Press,
Janda, R. ,Joseph B.(2003) On language, change and language change, in Handbook of Historical Linguistics, Blackwell, p. 3-180
Johnson B., Lam, S.K. (2010) Self-organization, natural selection and evolution: cellular hardware, genetic software, BioScience vol.60, No. 11, p. 879-885
Kauffmann S. (1993) The origins of order,: self-organization and selection in evolution, Oxford University Press
Kauffman S. (1995) At home in the universe, The search for laws of self-organization and complexity, Oxford University Press
Kauffman S. (2006), www. Beyond reductionism, reinventing the sacred.edge.org
Kirby S. (1998) Language evolution without natural selection, Edinburgh Occasional Papers in Linguistics,
https://pdfs.semanticscholar.org/913b/d6f5ed007104b6552e72ec96aa07e336133b.pdf
Kirby S. (2000) Syntax without natural selection: How compositionality emerges from vocabulary in a population of learners, in C. Night, M. Studdert -Kennedy, J. Hurford, eds. The evolutionary emergence of language, Social function and the origins of linguistic form, Cambridge University Press, p. 303-323
Lewontin, R.(1998) Evolution of Cognition, Questions we will Never Answer, in Scarborough, Sternberg, eds. An Invitation to Cognitive Science...vol.4 p.106-132, MIT
Lewontin, R. (2002) The triple helix, genes, organism and environment, Harvard University Press
Longa V. (2001) Sciences of complexity and language origins: an alternative to natural selection, Journal of Literary Semantics, 30, p.1-17
Longa V. ,Lorenzo G.(2014) Self-organization and natural selection: the intelligent auntie'e vade -mecum, Biolinguistics :8 p.130-140
Marcus G.(2008) Kluge, The Haphazard Construction of the Human Mind, Houghton, Mifflin, New York

Maynard Smith, J., Szathmary, E.(1995) The major transitions in evolution, Oxford University Press

Mayr E. (1988) Towards a new philosophy of biology, Observations of evolutionist, Harvard University Press
Mayr E. (2001) What evolution is, Basic books, Perseus Book Group
Morford J. (2002) Why does exposure to language matter?, in Givon, Malle, eds. The evolution of language out of pre-language, John Benjamins Publish. p. 329-343
Nisbett R., K.Peng, K. ,Choi I., Norenzayan A. (2001) Culture and Systems of Thought: Holistic Versus Analytic Cognition, Psychological review, 108 (2), p.291-310,
Oudeyer P.(2006) Self-organization in the evolution of speech, Oxford University Press,
Oudeyer P.(2011) Self-organization and complex dynamical systems in the evolution of speech; www.pyoudeyer.com
Prigogine I., Stengers E.(1993) Order out of chaos, man's new dialogue with nature, Bantam books
Schoenemann T.(1999) Syntax as emergent characteristic of the evolution of semantic complexity, in Minds and machines, 9, Kluwer Academic publishers, Netherlands , p.309-346
Schoenemann T.(2005) Conceptual complexity and the brain, understanding language origins, in Minett, Wang, Language acquisition, change and emergence, City University of Hong Kong, p. 47- 94

Schoenemann, T.(2017) Complex adaptive systems approach to the evolution of language and the brain, in Mufwene, S., Coupe, C., Pellegrino, F., Eds. Complexity in language, Cambridge University Press, chap. 4

Seeley T. (2001) When is self-organization used in biological systems. Biol. Bull. 202, (3) doi:10.2307/1543484

Smith K., Kirby,S., Brighton, H.(2003) Iterated learning, a framework for the origin of language, MIT, Artificial life, 9, p. 371-386

Steels L. (1995) A self—organizing spacial vocabulary, Artificial life,2 (3), p.319-332, MIT
Steels L. (2011) Self-organization and selection in cultural language evolution, in L. Steels, ed. Experiments in cultural language evolution, John Benjamins, Amsterdam, p. 1-37

Studdert-Kennedy, M. (1990) Language Development from Evolutionary perspective, Haskins Laboratories Status Report on Speech Research, SR 101/102, p. 14-27

www.haskins.yale.edu/SR101/SR101_02.pdf

Studdert-Kennedy M. (1998) The particulate origins of language generativity: from syllable to gesture , in Hurford, J., Studderd-Kennedy, M.,Knight, C., Approaches to the evolution of language, social and cognitive bases, Cambridge University Press, p. 203-221

Tomasello M. (2008) Origins of human communication , MITPress

Waddington C.H., (1953) Genetic Assimilation of Acquired Character, in Evolution, vol.7, no.2, p. 118-126
https://doi.org/10.1111/j.1558-5646.1953.tb00070.x
Zaefferer D.(1991) Semantic universals and universal semantics, Foris Publications

address for correspondence: svetlana.t.davidova@gmail.com