



Extended Abstract

Self-Organisation of Symbolic Information

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Introduction

The formulation of a unified theory of information still poses a fundamental scientific challenge [1,2]. Information may be present or being transmitted in two different ways, either in native form by physical structures or in symbolic form by coded sequences of letters, images, etc. The latter form is equivalent (i.e., necessary and sufficient) to the existence of life; there is no life without symbolic information processing, and there is no symbolic information without life [2]. In contrast, structural information may be attributed to any physical, unenlivened processes or structures and can usually be quantified in terms of entropy. The self-organised emergence of symbolic information out of structural information exhibits typical features of kinetic phase transitions of the 2nd kind and is referred to as a "ritualisation" transition [3], a term coined by Huxley [4] in behavioural biology for the development of signal-activity out of use-activity [5]. The origin of life, the appearance of human language or the establishment of social categories such as private property or money can be understood as ritualisation transitions [2,3]. All these transitions have in common that as their results, arbitrary symbols are produced and recognised by information-processing devices, by "senders" and "receivers" in the sense of Shannon's information theory, which had developed during an evolutionary process along with the actual set of symbols and of coding rules (such as "grammars" [6,7]), and replaced a related original non-symbolic causal chain.

A written text such as this abstract is typically a physical structure consisting of dark and light dots. The information carried by the text is in no way reducible to the physical properties of the given spatial distribution of dye; in this sense symbolic information is an emergent property. However, written text appeared as a result of the evolution of human language from more primitive signal systems used by

animals, and those in turn from elementary physical and chemical processes. Here, ritualisation is understood as a universal qualitative transition from elementary structural to emergent symbolic information properties in the course of evolution processes. Another emergent property that often accompanies symbolic information is its value, such as selective values in biology or exchange values in economy; this aspect will be elucidated in more detail in the presentation of Werner Ebeling at this conference.

Methods

Derived from thermodynamics [8] and the mathematical theories of bifurcations and catastrophes, the concept of kinetic phase transitions in non-equilibrium systems [9] appeared to be a useful tool also for the physical description of evolution processes which are thought of as potentially unlimited series of dynamic instabilities and subsequent steps of self-organisation [2,6]. In combination with empirical paradigms developed in population biology [10], ethology [5], evolution theory of culture and religion [11, 12], language theory [13,14] and economy [15], the striking qualitative similarity of the transition processes observed in those fields motivates their unified description from the perspective of self-organisation of information [2,3,16].

Results and Discussion

The very first ritualisation transition was the origin of life when chemical interaction of randomly assembled organic molecules became controlled by a primitive precursory genetic code, executed by catalysts forming a simple translation apparatus enclosed in a proto-cellular compartment [2,17]. Ritualisation was and is an extremely successful transition phenomenon in evolution that has been repeated many times after it once had happened for the first time, as briefly summarised in Table 1.

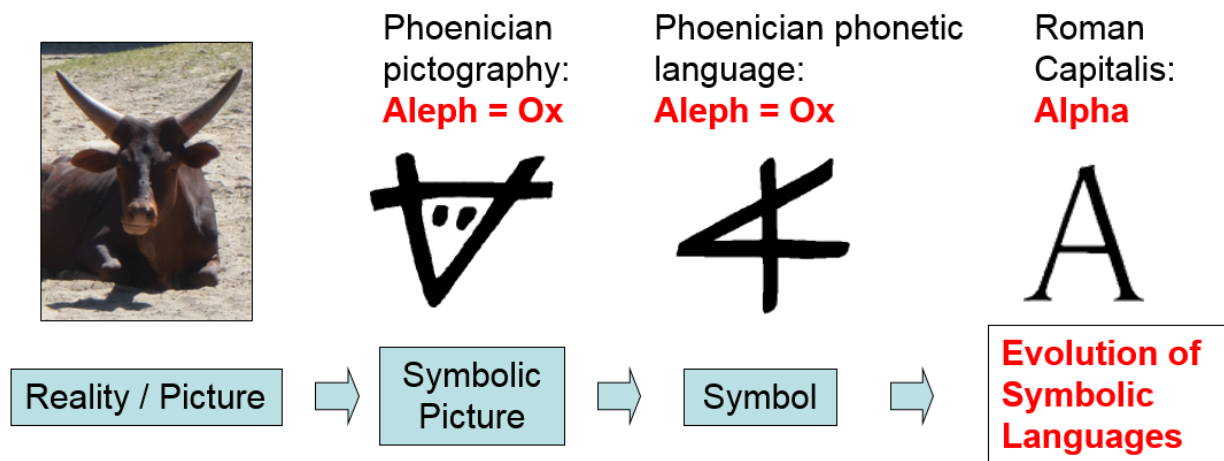
Table 1. Estimated time table of significant ritualisation transitions in evolution history (modified from [2]). Starting with the genetic code, each qualitative step of symbolic information processing gave rise to novel emergent properties, valuation and competition mechanisms.

Time BP	Evolution stage	Emergence of
4500 Myr	Random catalysis	Physico-chemical networks
3700 Myr	Genetic code	Biological systems
1200 Myr	Sexual reproduction	Sexual selective values
635 Myr	Morphogenesis	Multicellular organisms
518 Myr	Neuronal networks	Individual information gathering
2 Myr	Human spoken language	Human social systems
5500 yr	Written numbers	Book-keeping of personal property
2600 yr	Coined money	Market economy, exchange values
2600 yr	Greek natural science	Scientific information accumulation

Phase transitions of the 2nd kind own the characteristics [8] that the two phases involved (i) possess different symmetries, (ii) are indistinguishable at the transition threshold and (iii) cannot stably coexist

in space. The new symmetry that emerges during the ritualization transition is coding invariance; if one set of given symbols, say, Latin letters, is replaced one-to-one by a completely different set of symbols, say, computer bits, the functioning of the entire system will remain unaffected if sender and received are modified accordingly. This is illustrated by the letter “A” in Figure 1. In contrast, the picture on the left of Figure 1 cannot be arbitrarily modified without losing its meaning, the ox. The new, neutrally stable, so-called Goldstone mode related to the coding symmetry is found in every symbolic information system; it permits slow drift and diversification of the set of symbols and at the same time preserves a trace of its own evolution history. The paradox discussed already by Herder in 1772 [13] whether our spoken words are completely arbitrary creations of the human mind or are of traceable onomatopoetic origin may be explained this way.

Figure 1. Example for the ritualization transition in the evolution of the human written language. A physical object such as an ox is originally described by a symbolic picture (a “caricature”) which gradually develops into a mere symbol, losing any relation to the original object. The information represented by the final symbol(s) is an emergent property as its meaning cannot be derived from the physical dye distribution of letters such as “A”.



Conclusions

Symbolic information systems appeared exclusively during the evolution of life, if technical devices are counted as “honorary living things” [18]. Similarly exclusively, ritualisation may be the universal transition process by which symbolic information emerged from structural information. Accordingly, very different symbolic information system have universal properties in common which find their roots in the properties of the ritualisation transition, in particular, in the coding symmetry which fundamentally distinguishes symbolic from native information. In turn, the physical carriers of symbols possess native information; their physical structures are percussions of their own evolution history. The way how emergent symbolic information, the “soul”, became liberated from its original physical nature, the “body”, may be an evolutionary approach to a future unified theory of information.

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