Organism as a self-reading text: anticipation and semiosis

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Abstract

Signs appear as a result of the categorisation process which takes place with the interaction of texts. This can be interpreted as a primary form of anticipation learning. The behaviour of the sequential organic molecules with a high combinatorial potential gives rise to several features which are isomorphic with those of semiotic systems, and text. Organism is a text to itself since it requires reading and re-presentation of its own structures for its existence, e.g., for growth and reparation; it also uses reading of its memory when functioning. This defines an organism as a self-reading text. Anticipation is a property which primarily appears in autocatalytic cycles. For textual autocatalytic systems, anticipation could be represented as a sign.

Keywords: text, semiosis, categorisation, biosemiotics, evolution

1. Introduction

A rich arena for (apparently) new ideas and explanations of life phenomena lies in the triangle formed by biology, mathematics, and semiotics. The semiotic (signal) nature of the world is derived from the internal structure and functioning of organisms. "Biology (...) is, in itself and in all its aspects, natural semiotics with a pronounced proximity to deterministic chaos" (Eder, Rembold 1992: 60).

The thesis we develop here states that the ability of anticipation is based on the usage of signs. In other words, assigning meaning to any object could be taken as a model (or may be, even, as an equivalent) of anticipation. Signs, according to their definition, always inform about something else, thus creating relationships between distant, also temporally distant things. This is why we need to understand the origin of signs to explain the phenomenon and mechanisms of anticipation. Since the existence of signs is attributable to all living organisms (Sebeok 1994), a biosemiotic approach could be useful for furthering our understanding of "complex systems in general, and organisms *a fortiori*" (Rosen 1985: 166).

The existence of signs since the first living systems is a statement on which biosemiotics to a great extent stands. This has already been argued in the works of Uexküll (1940), Sebeok (1994), and later by Hoffmeyer (1997), Kull (1992, 1993) a.o. "It is important to realize that only living things and their inanimate extensions undergo semiosis, which thereby becomes uplifted as a necessary, if not sufficient, criterial attribute of life" (Sebeok 1994: 6). However, in the words of Pollack (1994: 12), "Although semiotics and molecular biology both have been remarkably fertile in recent years, few scientists or literary critics have been prepared to move out of their own familiar territories to learn from the other. (...) Yet if each strongly believes one type of text is worth reading, it is because both types of text - literary and genetic - may touch on the same matters of consciousness and mortality."

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2. Self-reading text

Text, according to Lotman (1986) and Torop (1982), is not a structure, but a process. A sequencial pattern is not necessarily a text, but it may become one through the process of reading. Thus, text is a readable pattern. Reading, at the same time, assumes recognition and translation, i.e. a building of new texts (e.g., texts in the reader's memory) as a result of the recognition of text. Also, all text is a result of translation, i.e. it has to be created through the translation, or reading of a previous text. Texts, therefore, always have a history. According to the notion of 'text' as proposed by the Tartu school of semiotics, besides verbal (discrete, linear) texts there may also be iconic (non-discrete, spatial) texts (Lotman 1990: 77). A feature of all texts is their reproducibility. Also, all text is both the result and source of translation.

Let us assume a system which is able to *translate* (i.e. to transfer structural information) some of its structures repeatedly into some other parts of this system (other structures), i.e. to make several pieces of the new structures on the basis of the first ones. We define translation as a process in which a reader transfers a structure into several other structures. *Text* is defined as a structure, which is a result of translation, and is itself translatable. A *reader* (or *translator*, synonymously) is a system required to execute translation, one which recognises text.

Consequently, it is possible to "translate" texts into structures, which are texts (i.e. which could be further translated or could be readable - for which there exists a reader), or into structures, which are not texts. This is accordingly autopoiesis and allopoiesis (Maturana, Varela 1980).

Since there could be several readers with different abilities, the text can not be connected to a particular reader. For instance, one and the same reader in different states could translate a particular text into different texts.

An organism could be viewed as a set of texts, which are translating each other and as a result building new texts. All these texts are components in cycles of replacement or reproduction, thus directly or indirectly also in cycles of self-replacement and self-production. Thus, an organism could be viewed as a set of reading and translating processes, in which some components of the organism read and translate other components of the same organism. Consequently, organism is a self-reading text.

The appearance of polycondensate molecules with a high combinatorial potential, which could be produced through the principle of pattern-matching using the example of other such molecules, serves very well to illustrate the building of these cycles. These molecules, despite being built on a digital principle, may also recognise analogue spatial patterns. Forming complexes with recognised molecules, they catalyse chemical reactions which otherwise could not proceed.

However, a molecule of a polynucleotide or protein *per se* may not necessarily be a text. To possess the properties of text, (1) it should be embedded into the *Funktionskreis* of reading and translation taking place in a living cell, and (2) it must have a reader since it is text only in relation to its reader, i.e. in these parts or aspects which are recognisable by the reader.

Thus, the question whether DNA is a language or not can not be solved on the level of DNA analysis alone; the whole cycle of recognition, reading and back translation should be considered. This is one of the reasons why the question has received quite ambiguous answers (Searls 1992; Tsonis *et al.* 1997).

Reading is always translating. Any reading, any translating is at the same time the building of a new structure, a new text. The new text might be expressed in the growth of the organism, the development of new organs, in the rebuilding of existing structures or relations, or in the generation of movements, patterns of muscle activities, the generating of a pattern of behaviour. Both, the text of the cellular pattern of sensoric organs, and the molecular memory, could be translated into behaviour.

3. Recognition

The basic process of life could be defined as a cycle of interlinked processes, consisting of texts producing other texts through the processes of recognition and translation.

Recognition as a primarily biological process means that an object is compatible with the recognising structure in an organism, whereas the recognising structure itself is a result of the previous recognition events, i.e. could have been modified by them. The recognition process includes the translation of the act where the compatibility is checked, into a structure (a text) which finally influences the further composition of the recognising structure.

In a sequence of recognition-translation events, different steps may have very different information content, or vocabulary. For instance, a connex of texts may include a text which recognises a result of recognition, i.e. a text or behavioural act which appears as a result of previous recognition. The act can be interpreted as a step in the recognition-translation sequence, only its vocabulary may be of a much lower order than the vocabulary of some other step, for instance a sensoric one. The higher information content of some intermediate step could be a result of its preservation by an intermediary self-(re)producible cycle.

A basic feature of biological recognition is its fuzziness, the potential for confusion. Usually, it is quite far from a bit-to-bit recognition, characteristic to digital systems.

Recognition also means distinguishing between some patterns, or categories. This means that in order for anything to be recognised (or, to be a sign), categorisation must already have taken place.

Thus, a sign, as something to be recognised, is not such an elementary or simple notion. This is where the biological approach, or biosemiotics, differs from the classical semiotic approach; for biosemiotics, which has to explain the origin of signs, the notion of sign can not itself be taken as elementary – as it is for semiotics which deals with the behaviour and dynamics of signs.

Signs, accordingly, correspond to the system of the recognising structures. The stability of the recognising structures appears to be a fundamental question for the better understanding of the topic.

4. Categorisation, or speciation

The process which organises a set (or system) of recognising structures should be a self-organising, autopoietic process. Due to its similarity (or certain isomorphism) to categorical perception, we may call it a process of categorisation (Stjernfelt 1992).

The categories, or recognising structures, are self-reproductive in the broad sense of the word (or autopoietic, more strictly). However, reproduction based on repetitive translation of texts is in this case obligatorily biparental, which means that any translation requires two initiators, between which the recognition takes place (i.e. which are compatible with each other). These two are, for instance, the text to be translated, and a text-in-memory which is used by the translator for recognition of parts of the text being translated.

This can be illustrated by a simple model. Let us take a large set of texts $\{T\}$, any one of them being characterised by a measure D, and having a limited life span. We assume that a new copy (or translation) of a text T_i (denoted as T_j, where $D(T_i)$ is close to $D(T_j)$) can be produced (i.e. translation of T_i may take place) only as a result of the interaction of T_i with another text T_k, compatible to T_i. The compatibility relation could be defined as $|D(T_i)-D(T_k)| < d$, where d is the width of the 'recognition window'. Assuming the pairing to be stochastic, the recursive continuation of the translations may change the initial distribution of $\{T\}$ along D. There are several important statements which can be proved for this system within quite a large range of parameter values: (1) If the initial distribution of $\{T\}$ is close to uniform, it cannot be stable; (2) the distribution pattern of $\{T\}$ is moving towards a state consisting of one or more peaks, separated by hiatuses, each of the peaks having a width close to d; (3) the absolute positions of peaks are not predetermined by the initial conditions, and are drifting (details of this model are given in Kull 1988). The peaks of this model will be called categories.

The categories, according to this theory, are self-sustaining entities, similar to biological species. According to the results of the modelling of the dynamics of biparentally reproducing organisms in the character space, the organisms are automatically driven to cluster into groupings which are separated from each other by hiatuses. It was shown that in the case of biparental reproduction, a wide even distribution cannot be stable. The range of compatibility determines both the variance within a category (species), and its minimum distance from neighbouring categories (the hiatus width).

The described result means that for a set of texts which reproduce as a result of reciprocal recognition, a categorisation into discrete species-like units automatically takes place. Serving as an explanation for the existence of biological species, this also serves as an explanation for the existence of the discrete words of a language in a potentially continuous space of possible utterances.

Since the actual position of a category in the parameter space of the recognised objects is determined by nothing else than by the former history of the recognition events (which includes context, i.e. the distribution of texts in the space D), the categories consequently primarily contain information about the object they will recognise. This could be seen as an early type of anticipation, specific to living systems.

Thus, the stability of recognising structures, and the existence of signs, is derived from the interaction of texts (or sequenced translatable patterns as long as they do not include signs).

5. Semiosis

Now, we may reconsider the question, whether signs, or signal interactions, are different from other interactions, and how they can be described in mathematical terms. According to our initial statement, this might show a way towards the more explicit formulation of the phenomenon of anticipation.

In the case of signal interaction, where a sign S is recognised by an organism O, we should not describe it as an algorithm where "S and O interact causing that and that" (or, "if there are S and O then that and that will happen"), since this would wipe out the difference we are seaching for (the difference which happens at the same time to be the difference between semiotic and non-semiotic, or between living and non-living).

It is more appropriate to say, that a sign S could be recognised by organism O via an intermediator E (which is a part of O), which is acquired during the ontogenetic or phylogenetic development of O (in other words: during the process of individual or evolutionary learning).

Thus, the conclusion that S interacts with O causally, cannot be inferred from the initial conditions, but is a result of the particular and incidental history of O (which includes many stochastic events).

The reason why the acquired E could be related to anticipation, i.e. to signal features, should stem from the way it was acquired. In cases of interactions of inorganic molecules, it would be senseless to assume that they have learned to do so. However, in the case of bio-organic compounds the situation is remarkably different. From the chemical point of view, CO_2 and ribulose-biphosphate do not have anything in common. They do not react with each other in normal conditions. But in the presence of an enzyme called Rubisco, they easily do so and give rise to the formation of almost all organic matter, in any green plant cell. Ribulose-biphosphate and Rubisco are themselves products of the same cells which they are supplying with the product of this reaction as a substance for building themselves among others. Rubisco, at the same time, may be different in different plant species, and may also differ between individuals of the same species (in the same way that any person pronounces this name in a slightly different way). More interestingly, Rubisco does not recognise CO_2 very exactly, it often mixes it up with O_2.

In a similar way, no biological processes have only two interactors - all have at least three. The third is the component enabling a connection to be made between the other two, which may themselves not have anything in common in a physical sense. The connection between the two is made due to the properties of the third which have evolved through an historical process analogous to learning.

Semiosis, in its most fundamental sense, could be defined as the appearance of a connection between things, which do not have *a priori* anything in common, in the sense that they do not interact or convert each other through direct physical or chemical processes. However, as far as the relation between them once established is nevertheless intermediated by physical or chemical processes, this infers that the relation is semiotic as long as it is established through learning.

Also, semiosis is a process which gives a system the ability to refuse to participate in a particular reaction. Two things, which would usually react due to their chemical affinity or some other physical reasons, may not react when the intermediator, i.e. the third component of the process, has bound one of the reagents. Or, in some other cases, the reaction is inhibited due to the absence of the intermediator. This may be how semiotic freedom initially appears.

Since in these processes, the intermediator must be present before the process can take place, the production of the intermediator anticipates the whole particular process.

Semiosis is not simply a ternary (triadic) interaction, but a cycle which includes it. This cycle can be compared to the *Funktionskreis* according to J.v.Uexküll (1928). Semiosis is the cycle of being, in a very deep sense. (It includes a temporal characteristic, however, it does not include a clock. Despite this, semiosis creates time of being.)

Signs are segments of text which become identified as a result of double translation, i.e. in the interaction of (at least) two different languages. This is very close to Lotman's statement about the necessity of at least two different languages for the existence of any language (Lotman 1990).

In one and the same text, different readers may recognise different signs. Consequently, text cannot be defined as a sequence of signs. Accordingly, we propose to use an independent definition of text, signs being secondary in relation to text.

Kawade (1996), who also propose to apply semiotic terminology to cellular chemistry, however, mainly emphasised the functional and intentional aspects of simple biological processes. Accordingly, he concludes that "the impressive similarity of the genetic information system to language (...) is mainly concerned with the question of what are the basic elements of the system and how they are arranged in linear patterns to yield significant structures. The realm of meaning, semantics, in contrast, comes to the fore when physiological, rather than genetic, aspects of living systems at the molecular level are considered" (Kawade 1996: 197-198). When the hardly defineable intentional aspect is taken as a starting point, we may loose in the clarity of the explanation, and still the principal differences between the semiotic and non-semiotic on the level of mechanism do not become easily defined. My idea is to concentrate on some physically interpretable special features which arise together with the biological molecules, but which simultaneously possess a semiotic dimension. These are, mainly (1) the great combinatorial potential, so great that the features of even a minute part of the combinations are not physically surveyable, any single one of them being multifunctional; (2) the ability of many of these sequential molecules to catalyse reactions which otherwise cannot take place, and which turns all biological reactions into three-component, triadic processes; (3) the existence of mechanisms which allow these molecules to be continually reproduced in self-renewable cycles so that the primary structure can be preserved with quite high precision; (4) the learning ability of these cycles.

6. Learning

Aristotle started his "Metaphysics" with a discourse on learning. He makes a difference between animals, who can memorise, i.e. who can learn, and other organisms who cannot. But we should notice, that not all the new texts, which arise as a result of translation and can be used afterwards as a memory, are equivalent to learning. "If one is unwilling to abandon the assumption that activity requires knowledge, one risks being caught on the horns of the ancient dilemma: How can one acquire knowledge if one can't recognize it? And if one recognizes it, doesn't one already have it?" (Oyama 1985: 57).

Fodor (1980; ref. Oyama 1985: 178) gives a sophisticated version of this argument; "he seems to conclude that the only way out of the nativist impasse is to reformulate learning, which he treats as hypothesis formation and confirmation". According to Oyama (1985: 178), "it is not only learning that must be reformulated, but all of development, since, as we can see, traditional conceptions of ontogeny lead to the same paradox as do traditional conceptions of learning."

Kauffman (1993: 229) has stated that learning itself may be the fundamental mechanism which converts chaotic attractors to orderly ones.

The learning of something new is based on noticing a difference, the difference between the text-in-memory and the text-readable, between the etalon and the object.

The learning of something new assumes, that the text-in-memory is changeable, that it could be replaced. Memory is that which can be forgotten. This would be the case, if the text-in-memory is itself a self-back-translating text. Or, in more biological terms - the learnable memory should be a population of self-reproducible elements.

Learning in the sense we use it here is equivalent to the process of categorisation - the appearance of new peaks of recognisable form, or a change in their pattern.

Thus, I do not think that the automatic transformation of texts is in itself life. It should at least include the ability to learn, i.e. life assumes a learnable transformation of texts.

However, there are evidently several different types of learning: (1) slightly changing of a piece of memory, replacement of a text-in-memory with a new, better adapted or more adequate pattern; (2) making a distinction, i.e. two things, which were previously recognised as one, are recognised as two different things; (3) relating two things which were previously unrelated.

According to Wesson (1991: 245), "Within the animal's framework of response, however, it can be trained; the experimentator has only to find means of rewarding it. And animals train themselves, that is, learn. They move about and seek novelty, especially in unfamiliar circumstances. To explore means to make choices; if choices entail rewards or punishments, learning results. Ethologists write constantly of choice, search, avoidance, and strategy."

Despite the existence of different models of learning, one which works as categorisation simultaneously with the entropic processes of forgetting, could be applicable for both phylogenetic and ontogenetic learning.

7. Memory

Memory is simply a certain type of text. It happens to be far from easy to define which of the texts are memory, since it is a feature of all texts to be readable and re-writeable, and also the history of any text includes learning. A text is a memory if it has relatively higher stability. Memory is relative and has many levels. E.g., mRNA could be a memory for an enzyme, whereas DNA could serve as a memory for mRNA. The problem of defining memory is so complicated since the processes in which memory acts are cyclic. E.g., DNA cannot work on its own - it requires ready enzymes which can read it, which can (remember how to) recognise some sites on it.

A way to distinguish memory from all other texts is to assume that memory should work at least in some processes as read-only.

The information stored in memory does not include directly any information about the external environment; what is remembered is a part (a partial state) of the system itself.

According to this view, the genome is not an active component. It is even less active than a programme for a computer. The genome is viewed here as a rich sequence of patterns, some of which can be recognised by cells and used to restore some other structures necessary for the cell. In evolution, genomes may become longer, but it is very much up to the cell whether to use the new patterns or not. Initially, the new patterns have no meaning, but they may achieve it through recognition and utilisation. Thus, possibly meaningful patterns are primarily determined by the existing recognising structures of the cell.

We should additionally note the fact that usually it is not the structures themselves that are recognised in genomes, but the patterns which mark the starting points for detailed reading. However, this does not change the issue. The point is that memory to be used does not work like a structure repeated in its entirety. In memory, there are many sites which can be distinguished and recognised, and which after being recognised can be used for restoring some patterns in detail.

Memory, accordingly, works as an anticipatory text.

8. A note on evolution

Biological self-reproduction is a production of texts. A system able to proceed retranslation is, in other words, a reproducible, or self-reproductive system (Emmeche, Hoffmeyer 1991, 16). It should be noted here that the notion of *self-reproduction* does not assume the exact identity of the original and product.

Since the translation may not be exact, it may happen that, in the course of repeated retranslation, the retranslatability could be lost. But here we meet an interesting phenomenon - if the translation also creates the translator, then it has a stabilising effect, i.e. it diminishes the variability of retranslations. (This phenomenon was investigated under the heading of error catastrophe in the case of RNA transcription, where it was shown that if there are too many mistakes in transcription, an *error catastrophe* appears; this could also be viewed the other way around - if the retranslation becomes exact enough, it will stabilise itself.)

Due to the non-exactness of translations and entropic processes, the reproduction is generally not transitive: if T_2 is a copy of T_1, and T_3 is a copy of T_2, T_3 may not be a copy of T_1. Thus the term self-productive could be more apt here, which has also been used to define autopoietic systems.

All of Darwinian biology, from Fisher's theorems to Dawkins' memes, is based on the usually hidden and simply unformulated assumption of the transitivity of reproduction. Namely, the mechanism of natural selection assumes that what is selected will be propagated without the loss of its identity. Indeed, in the case of the transcription of small pieces of DNA the process seems to be very close to this assumption. The stability of the material of genetic memory has been concluded to be the important reason for the existence of life. Any change in the structure during reproduction has interpreted as a mutation which breaks the inheritance. For natural selection to be effective, the isolation between reproducible elements was consequently a requirement for evolution. Alternatively, in semiotic biology, if we define reproduction as a non-transitive process, many basic consequences become quite different. Taking the whole genome which is the *sine qua non* for the development of an entire organism, or its greater part, reproduction is almost never exact; the reproducible elements may not be fully isolated. This makes "genetic egoism" senseless - the genomes of the progeny are not identical to the genetic memory of the parents, the context of genes in particular has changed. Nevertheless, there is a stability, but this stability is, according to the biosemiotic view, a result of certain cyclic recognition processes, which we identify with semiosis. Despite minor changes of structure or larger changes in the material, and even in the absence of DNA in some cases, the phenomenon of life may exist.

It is quite obvious that stochastic changes in memory cannot be the main driving force for development. The driving force of development could be recognition. As a result of recognition, memory is rewritten - either its neural and individual (non-genetic) texts in the case of ontogenetic learning, or genetic texts in the case of evolutionary learning. Which parts of the memory are preferably rewritten, depends on the results of recognition. Thus, in evolutionary learning the learning system is a population, and in the case of ontogenetic learning it is an organism.

The primary changes in evolution can be viewed as the changes in organisms as a result of a new recognition situation. A directed change in memory may follow, i.e., the stochastic change in memory may consolidate the change which has already occurred in the behaviour or structure of the organism. This could usually be the forgetting of the unused.

Thus, "although the products of evolution are a mess, they are a functional mess, as organisms learn how to cope with their turbulent genomes and with the vagaries of the environment" (Dover 1997: 92).

9. Anticipation

A change in behaviour precedes the corresponding directed change in memory. Changes in organisms, thus, anticipate evolutionary change. It is probably very common that epigenetic changes precede the corresponding genetic ones.

However, anticipation which is common for sign processes, seems to work in another way. Namely, a sign is translated into interpretation, which will work as an interpreter in some further act of semiosis (i.e. it corresponds to something which will be recognised afterwards). This corresponds to a situation where a result of reading is a reader.

The latter formulation gives us a basis for identifying adaptive evolution with anticipatory behaviour (this statement holds in the framework of the semiotically reformulated description of evolution, but may not be true when using neo-darwinian terminology).

In all autocatalytic cycles, the absence of a substrate leads to an increase in the concentration of the substance which would react with it; thus, the concentration increase anticipates so to speak the appearance of the substrate. This may serve as a useful simple model for anticipation phenomena. In a branched textual cycle, which includes behavioural acts, the expectancy caused by a temporary lack of a certain component, makes its identity with anticipation become more evident. This is anticipation in a *Funktionskreis.*

Anticipation is the key to survival, but this key derives from the basic features of semiosis: its unlimited recursive translation processes, with at least two languages interacting.

What we described, is the development of language-like structures within an autopoietic system. Our hypothesis states that the ability for anticipation is a result of the appearance and usage of signs, which is congruent with the appearance of a semiotic system from a non-semiotic one.

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