The central dogma: A joke that became real

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The Central Dogma: A Joke that Became Real*

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Introduction

I still remember how I was taken by a mixture of joy and - well, let me admit it - a bit of annoyance the first time I came upon one of Tom Sebeok's papers. This was in the late 80es, and probably in 1988 because I remember that Claus Emmeche and I had just finished writing our joint paper on "Code-Duality and the Semiotics of Nature" which, by the way, we did not know where to publish and which did not appear until three years later in "On Semiotic Modeling" co-authored by Myrdene Anderson and Floyd Merrell (Anderson and Merrell 1991; Hoffmeyer and Emmeche 1991).

To me, coming from biochemistry, Thomas Sebeok was at the time just a name, and I didn't know anything about his intense interest in the study of living beings in general and in the semiotics of their activities in particular. But now, just there in the paper I held in my hands, a paper titled "The Doctrine of Signs", this linguist professor had the audacity to compare among many things a Kremlin-watcher who "observes the proximity of a member of the Politburo to the Party Secretary on Mayday and makes conjectures about his current status" to a peacock which "displays to a susceptible peahen; she circles rapidly, squats, and coition ensues" (Sebeok 1986). That the behavior of a Kremlin-watcher and a peacock might have something in common was not at all an idea that stirred up my inner waters, but I would never have dared to say so in an academic paper.

In the paper Sebeok proceeds to make clear that what connects such diverse phenomena as these is *semiosis* and he observes that "only living things and their inanimate extensions undergo semiosis, which thereby becomes upliftet as a necessary, if not sufficient, criterial attribute of life." He even goes on to assure that by 'living things' he is not just referring to "organisms belonging to one of the five kingdoms...but also their hierarchically developed choate component parts, beginning with a cell, the minimal semiosic unit". And this logically brings him to the field he himself has termed *endosemiotics* (Sebeok 1972), the study of the bodily taming of metabolic energy flows through the integrated networks of semiotic controls.

Having just - in a joint effort with Claus Emmeche - initiated the development of a Peirce inspired semiotic analysis of natural processes, I was of course enormously pleased by Sebeok's wonderful paper, and it was very encouraging indeed to see such a powerful support for the biosemiotic idea emmanating from what was supposed to be the opposite brink of the Great Cartesian Canal. I think Claus and I expected our views to be attacked even more forcefully from the humanities than we were sure to be attacked from the established biosciences. But then I guess that everybody can also understand my slight annoyance in seeing that the ideas we thought we had developed ourselves were in fact already available and contextualized inside a tradition with which we were not overly confident.

Sebeok later has told the story of how biosemiotics was independently invented several times throughout the preceeding century (Sebeok 2001). First in the hands of Jakob von Uexkull, then through the work of the Austrian ethologist Heini Hediger, and then again by the Italian immunologist Giorgio Prodi (Sebeok 2001). Also the German medical psychologist Friedrich Solomon Rotschild might deserve to be mentioned in this connection. In 1962 Rotschild not only introduced the term biosemiotics but also suggested a view of natural processes closely corresponding to modern conceptions of biosemiotics. Thus Rotschild made the far-reaching claim that: "Protozoa, invertebrates, vertebrates, and finally man appear as four developmental stages of subjectivity. In each stage a new sign system overlays the already established ones and makes the unfolding of a new and higher level of experience possible" (Kull 1999b; Rotschild 1962). Unfortunately Rotschild's work did not draw any wide recognition outside of his own field, and it was only recently digged up by the efforts of Kalevi Kull in establishing a historical account of the development of biosemiotics (Kull 1999a). For the sake of completeness also the Russian-Estonian tradition to the study of theoretical biology from which Kull himself has originated should be included here and it should be noticed that Yuri Stepanov used the term biosemiotics as early as in a book from 1971 (Stepanov 1971).

In spite of all these remarkably original and in fact courageous attempts to found a biological sign theory future historians of science are likely to credit Thomas Sebeok not only for his own relentless and clearvisioned work through four decades on developing a semiotics of living systems at all levels of complexity but also for his absolutely untiring and ultimately successful attempts at explicating the necessity for the inclusion of biosemiotics into the grand family of semiotics.

This work is why I am standing here today and I am extremely proud and honored to accept the fellowship called by Thomas Sebeok's name.

The Fallacy of Digitalism

Inside biology itself biosemiotics is still only a marginal framework. One major obstacle for biology in arriving at a properly seimotized understanding of natural processes is what I would like to call *the fallacy of digitalism* i. e., the more or less automatical preference for explanations that ascribe primacy to digitally coded information or sees such information as an explanatory bottomline. For decades biological theory has focused much of its attention on the explanatory power ascribed to sequential information stored in nucleotidebased macromolecules, DNA or RNA. It has been a widespread assumption that evolution is ultimately explainable in terms of the dynamics of the gradual accumulation of sequential information inside the gene pools of evolving lineages or that ontogenetic development is largely controlled by a digitally coded masterplan for the regulated protein synthetic activity of the growing embryo.

The strange thing about digitalism is that nothing in our immediate human experience supports the idea that formalized digital descriptions not only preceeds but even causes spatio-temporal events. True enough, modern technical installations, such as buildings, cars or missiles, are all the products of comprehensive mathematical modelling. But nobody suspects that these models themselves suddenly begin to construct buildings, cars or missiles. Clearly the digital models must be interpreted by e.g. engineers, and also lots of construction workers are needed for the actual production of these technical items.

Nevertheless, this is probably where we find the source for digitalism. One of the major governing principles behind the industrial society has been the separation between plan and execution. And since execution was supposed to be deterministically dependent on the plan interpretation was not a part of execution. In other words, all creativity was delegated to the makers of the plans, not to the makers of the products. If we now take this as a model for organic evolution or for development and then substitute God or natural selection for the makers of the plan we will arrive at digitalism

Thus, the fallacy of digitalism might seem to be yet another example of the general human propensity to project dominating social structures of one's own time onto nature at large. Seen in this light digitalism belongs to the epoch of industrialized production and may eventually be expected to loose its grip on the minds of scientists in proportion to the fading dominance of this particular way of production. In fact, the strict separation of execution and interpretation is not at all typical for advanced sectors of the present economic systems. On the contrary semiotic competence is a more and more highly evaluated qualification of the work force. And, in fact, digitalism in science is now increasingly challenged by models in which *embodyment* is seen as an essential part of execution (note 1).

It should be noticed that biology is far from alone in having committed itself to the digitalistic fallacy. In fact, essentially the same kind of preference is operative in other branches of modern science dealing with emergent systems such as cognitive science, linguistics or robotics. For instance, in cognitive science it has been a mainstream view that human mind should be characterized as an information processing system with specific storage and processing capabilities, running a production system that operates on internal representations described as a physical symbol system. And from the beginning of the cognitive revolution this "physical symbol system" was seen as absolutely irrelevant for its workings (Newell and Simon 1975). The idea of language as an inherent property of our computational brains and ultimately coded for in our genes belongs to the same strand of thinking.

As is well known the "symbolic paradigm" has come under attack from a very successful "dynamic approach" developed by among others Tim Van Gelder and Robert Port (Van Gelder and Port 1995), and so-called "self-organization" has been instituted as an alternative explanatory principle to design-through-information (Kauffman 1993). At another level of investigation semantic linguistics has forcefully defended the "embodied nature" of natural language (Lakoff and Johnson 1999).

The revival of the body inside biology may seem to be a paradox, and so it is. The genocentric neoDarwinian understanding of the evolutionary process, which has dominated biology for so long, does not put much emphasis on concrete organismic activity or "phenotypical behavior" which is mostly seen simply as a derived parameter essentially determined by the interacting forces of selection and mutation both of which are sort of external to the organism proper. The organism in other words is not seen by neoDarwinian ortodoxy as an autonomous factor in its own evolution.

This disembodied model of nature however no longer goes unquestioned. One major reason to suspect the legitimacy of this model is the fact that the complexities of the environment are not at all matched by a corresponding complexity of the genomic instructions (Emmeche forthcoming). Organismic semiotic competence rather than genetic prespecification must have been the solution to the problem of dealing with environmental heterogeneity. Or, in other words, while nobody denies that behavior depends on genetic instructions its release is obviously always under semiotic control.

One particularly interesting source for environmental change was called *niche construction* by Odling-Smee (Laland, Odling-Smee and Feldman 1996; Odling-Smee, Laland and Feldman 1996) To varying degrees organisms choose their own habitats, choose their mates, choose and consume resources, generate detritus, and construct important components of their own environments (such as nests, holes, burrows, paths, webs, dams and chemical environments). In addition, many organisms choose, protect, and provision 'nursery' environments for their offspring. To a large extent therefore organisms themselves modulate or sometimes deteriorate their own niche conditions.

Niche construction points to a more general challenge to the neo-Darwinian interpretation of evolution which has become known as developmental systems theory (Griffiths and Gray 1994; Oyama 1985). Developmental systems theory holds that genes are just one resource that is available to the developmental process and that there is a fundamental symmetry between the role of genes and the role of other kinds of developmental resources whether these are environmental or epigenetic. The integration of this fascinating new line of evolutionary thinking into Jakob von Uexküll' biology opens a promising avenue for further biosemiotic study [Hoffmeyer, forthcoming b #726].

Although genocentrism is now challenged in biology it remains nevertheless a dominating bias which is not likely to recede in the absence of a more profound reframing of the ontological presuppositions of the discipline. Foremost among these is the idea of digital information as a causative agent, which became canonized in the form of Francis Crick's famous "central dogma". Legend has it that the term dogma was originally meant as a joke, which to the extent that a dogma is most often associated to an unquestioned system of principles or tenets upheld by the church is probably true. That Francis Crick should seriously have equated his own ontological beliefs to dogmas in this sense is certainly not very likely. Somewhat paradoxically however the central dogma did in fact attain the role of a dogma in the clerical sense, i.e. as a largely unquestioned or unquestionable ontological principle which served to legitimize biological digitalism.

The Central Dogma

In Francis Crick's original formulation the central dogma simply implies that: "once 'information' has passed into protein it cannot get out again" (Crick 1988). This is explained to mean that something, termed information, can only be "passed on" or "flow" in one direction, that is from DNA to RNA to protein, and never in the other direction (figure 1).

FIGURE 1

It was later shown that "information" might under certain peculiar conditions run backwards from RNA to DNA (in the presence of reverse transcriptase, an enzyme of viral origin) so that the left arrow in figure 1 might sometimes be inversed. As long as the right arrow cannot be inversed this does not however contradict the fundamentally antiLamarckian (note 2) implications of the dogma. The question I want to pose here is not about the direction of the arrows. The question rather is what do the arrows mean? What is the nature of this entity, information, which so elegantly got transported away from master (DNA) to pupil (protein)? Francis Crick himself was quite explicit: "Information means here the precise determination of sequence, either of bases in the nucleic acid or of amino acid residues in the protein". I shall not exhaust the reader's patience by entering the endless discussions on the proper understanding of the term information but I think it can be safely said that 1) no agreement on the meaning of this term has been reached or is even in sight, and 2) for the practicing biologist the central dogma always meant simply that "instructions" were passed on from DNA to protein. In the absence of any rigid definition of the term information the instructional conception of this word imperceptibly slid into the matrix of tacit metaphors nourishing the minds of modern biologists.

The adoption of an instructional (or specificational) understanding of the "something" transmitted from DNA to protein is no innocent move however. It immediately raises questions about how we should understand the relation between senders and receivers of this "information": are they supposed to be connected through a causal relation? A yes to this question would seem to violate Norbert Wiener's famous statement that "Information is information, not substance or energy. No materialism that fails to admit this can survive today" (Wiener 1962, 132). The concept of a passage between macromolecules of something, which is neither substance nor energy, feels foreign to materialistic science.

I find it hard to escape a feeling that the central dogma, and digitalism in general, hold such a power over the minds of modern scientists because of the deep dedication of post-Newtonian science to efficient causation (in the Aristotelian sense) as the only permissible kind of causation in nature (note 3). Since the ribosomes on the surface of which the nascent protein molecules are actually assembled from their amino acid monomeres is physically moving along a messenger RNA molecule, this mRNA molecule has to exist temporally prior to the nascent protein, and likewise any concrete gene must be temporally prior to the mRNA molecules transcribed from it. When only efficient causation is permitted this means that the temporal priority of DNA must also imply its causal priority (note 4) i. e., digital structure preceeds and causes its non-digital effect. Thus the need for something, information, to bring out this causality. Or, in other words, if you subscribe to a Newtoniam entailment scheme, and if you - accordingly - subscribe to digitalism, how else could you explain the semiotic character of protein synthesis than by imposing a factor, a kind of "instructions" or "specifications", that somehow is capable of 'passing' from one molecule to another? Call that factor information (note 5).

In a Peircean perspective there is nothing that "flows" from DNA to RNA to protein. In stead what goes on is *semiosis*, i. e. the organized cellular system interprets the digitally coded messages in the chromosomes according to the changing contexts in which the cell or the organism finds itself. This understanding immediately brings us far beyond the Newtonian conception of cause since the Peircean sign is itself the essence of a final cause (Santaella-Braga 1999; Short 1983). Saying this, however, it must immediately be added, as Lucia Santaella-Braga points out, that unlike Aristotle "Peirce did not attribute the influence of final causes to perfection, nor to goodness, nor to the pure and primeval source of activity". Indeed the Peircean understanding of final causation expresses a strange anticipation of modern interpretations of thermodynamic theory. Thus in Helmuth Pape's formulation "The difference between Peirce and Aristotle ultimately depends on Peirce's insight, which he was the first in history to formulate, that the possibility of irreversible developments of chance distributions is a necessary condition for all kinds of final causes, including purposes, even if they are chosen because of their goodness" (Pape 1993) quoted in (Santaella-Braga 1999). Final cause then is not identical to purpose and Peirce was quite explicit here: "It is a widespread error to think that a final cause is necessarily a purpose. A purpose is merely that form of final cause which is most familiar to our experience" (*CP* 1.211). And: "purpose is the conscious modification of final causation" (*CP* 7.366). Unfortunately this error is as widespread today as it was in Peirce's own time. Science has not attempted to see human purposes as an instantiation of some broader principle pertaining to all of nature. Rather it has excluded purpose all together from its domaine thereby leaving it as an alien feature of human life for the humanities to consider.

In recent years, however, quite a few biologists and philosophers have claimed that efficient (Aristotelian) causation cannot exhaustively account for the dynamics of living natural systems (Juarrero 1999; Riedl 1997; Rosen 1991; Salthe 1993;

Ulanowicz 1997). I cannot resist adding that this turn in ontological perspective towards a richer concept of causality makes the idea of "information flow" look a little like the ancient idea of phlogiston. Until the French chemist Antoine Lavoisier in 1783 proved that combustion was caused by absorption of oxygene it was believed that a mysterious component, a "subtle fluid" called phlogiston, was given off from burning substances and that this liberation of phlogiston was the cause for combustion. Thus, inflammable materials like fats or oils were supposed to be exceptionally rich in phlogiston. Even Joseph Priestly who had himself a few years earlier discovered oxygene stuck to the phlogiston theory to the end of his days. As one philosopher of science observed, Priestly discovered oxygene but Lavoisier invented it.

I do not claim that clever definitions of "information flow" has not been given or that this concept might not in principle be used to explain what I prefer to call the semiotic dimension of life. In fact, even phlogiston may be seen as a sensible concept since in modern chemistry phlogiston corresponds to the very well-respected class of elements called electrons. What I would maintain is that as soon as we leave Newtonian prejudices behind us the idea of an "information flow" becomes an unnecessarily complex way of understanding biosemiosis, and worse yet an idea which tends to fool less sophisticated minds as much as the chemists were fooled in the 18th century by the phlogiston theory. In fact I would submit that the whole idea of biological information has served to prolong the time span before reductionist biology would have to give up its unworkable metaphysical prejudice.

Semiosis as the Definition of Life

I hope that this analysis has clarified one of the two main reasons why biosemiotics had to be reinvented several times throughout the preceeding century. The commitment of biology to a Newtonian conception of causality made it difficult for mainstream biology to accept the triadic conception of the signprocess as a theoretical entity. In stead biology was lead to accept the digitalistic view of causality embedded in the idea of an information flow as instituted by the central dogma. For this reason those genuinly semiotic theoretical claims which were indeed formulated could not be integrated into the unified theoretical structure of biology and they would not therefore get any wide reputation inside biology proper. As Thomas Sebeok himself observes, commenting on Hediger's work : "One of the sundry riddles that mar the gradual coming into view of modern biosemiotics — the second iteration, if you will — is the neglect of Heini Hediger, whose lifelong attempt to understand animals surely marked a milestone in the elucidation of this domain, providing it with a particularly beneficial empirical footing"(Sebeok 2001). The same could be said, I think, although to a lesser extent perhaps, about the reception of Jakob von Uexküll's work.

The other main reason why biosemiotics was reinvented several times in the preceeding century is more straightforward. Biology, considered as a unified science, is supposed to bridge the enormous evolutionary gap left in between physics and the humanities, i.e. the gap between the primeval mud, the "ursuppe" as it is called in Danish and German alike, in which life arose some 3.500 million years ago, and the origin of modern man some 0,1 million years ago. For historical reasons biology clearly sees itself as one of the natural sciences and thus belonging to the mud part of this Cartesian divide rather than to the man part of it. There is however no obvoious reasons for this choice (note 6) and the fact of evolutionary continuity between animals and human beings implies a strong temptation for biologists to describe animals and life in general as more humanlike than mudlike. Thus the idea of a semiotic animal or life world is in a way quite obvious once you have put aside your Cartesian inclinations.

The very absurdity of seeing man as the product of a natural history taking place in a reversible universe, i.e. a universe in which time is pure fiction, has made it easy for the humanities to dismis the questions raised by the animal origins of mankind as irrelevant. But for thoughtful biologists there has always been a strong temptation to dismis in stead the belief in the reversible universe of classical physics, relativity, and quantum mechanics. Such was the choice taken by the vitalist German biologist Hans Driesch or for that matter by the french philosopher Henry Bergson. The problem for Driesh and for Bergson was that at their time thermodynamics was not yet developed to support such ideas, and in stead they had to rely on mysterious vital forces in their attempt to account for the the problems of morphogenesis. The last ten year's developments in a diversity of areas of modern science, such as non-equilibrium thermodynamics, non-linear dynamics, chaos theory, and complexity research has reversed this situation and it would be very interesting to reinterpret the work of Driesch and Bergson in the light of these new insights.

For many biologists vitalism in general and Driesch's theories in particular came to signal the dangers of mixing science and philosophy and thereby, I think it is fair to say, came to work as an excuse for not considering the philosophical implications of their research. Seen in retrospect this judgment may be based on a somewhat too euphoric understanding of the capacity of molecular biology to solve those problems on which Driesh had to give up. The smart idea of the gene as a sort of information may have anaesthetized that critical nerve of biologists who otherwise might have made them question the validity of such an easy bridge between units of substance (DNA segments transmitted down through generations) and units of form (genes capable of instructing a spheric and homogenous egg to become an organism in three dimensions).

Now, looking into the future, I think that a general trend in many scientific areas and certainly in biology is a trend towards a more pluralistic and tolerant climate. That such a trend exists in evolutionary biology was one of the main tenets of a recent book co-authored by the philosopher David Depew and the biochemist Bruce Weber (Depew and Weber 1995). I find it reasonable to expect that biosemiotics will slowly find its way into the very diverse garden of biological sciences. As such it will grow, we may hope, to become one strong resource for biological theorizing among others. But it may not become a conventional university-based discipline, and nor should we, as Sebeok has recently observed, perhaps want it to become one: "such formal units of knowledge production are by no means the only possible, let alone the most desirable, type of reputational system of work organization and control. Semiotics, and, *a fortiori*, biosemiotics, is, or should be, a field committed to producing novelty and innovations, not much else" (Sebeok 2001).

Considering how it often happens that bright ideas which were once revolutionary gradually becomes suffocated by fame, tradition and rigidity it may be wisest to agree with Sebeok here. Let not biosemiotics become a discipline of its own. Rather let it stay a field in the sense given by Richard Whetley: a "broader and more general social unit of knowledge production and co-ordinations" Such fields, says Sebeok, conceived as "relatively well-bounded and distinct social organizations which control and direct the conduct of research on particular topics in different ways," possess identities that are by no means always identical with employment or education unit boundaries. They "vary in the degree of cohesion and autonomy from other [academic] structures, but constitute the major social entities which co-ordinate and orient research across a wide variety of situations.... They reconstruct knowledge around distinct 'subjects' and their organization and change are crucial aspects of intellectual work and knowledge production in the modern, differentiated sciences" (Whitley 1984) (quoted in Sebeok 2001).

That biosemiotics would become a scientific field in this sense should be seen as the criterium of success, and I actually believe that biosemiotics is going to fullfil this criterium. This is to a very large extent due to the unique work of Thomas Sebeok who against all odds and for more than 30 years energetically persued his vision that "a full understanding of the dynamics of semiosis (may), in the last analysis, turn out to be no less than the definition of life" (Sebeok 1968; Sebeok 1985 (1976)) 69), a vision, I should add, which proves that Thomas Sebeok is not only a distinguished semiotician but also one of the greatest biologist of our time.

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Notes:

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1) That processes are now seen as *embodied* implies the growing understanding of digital prespecifications as essentially passive, i.e. dependent on the autonomous activity of spatio-temporal continous structures, or bodies. While a triadic semiosic understanding of this relation seems obvious such is not normally implied or at least not explicitely.

2) The term Lamarckian is used here in the conventional Darwinist sense as referring to a belief in the inheritance of acquired characters. This use of the term is most unfair to Lamarck who didn't consider this particular part of his grand theory to be central. In fact at Lamarck's time around 1800 everybody believed in the inheritance of acquired characters. The irony is that even Darwin did!

3) The Newtonian curtailment of causality to just efficient causality is of course itself reinforced by the historical success of that industrialized production system which essentially consisted in the merciless implementation of this "nothing-but-ness" as a basic principle for the nature-culture interface.

4) If formal causation was seen as an acceptable process protein synthesis might have been explained through reference to the holistic cellular setting of the whole process.

5) I guess this captures the essence of Sahotra Sarkar's attack on the information concept of molecular biology which he sees as misleading and unnecessary (Sarkar 1996). According to Sarkar no information flow is involved, chemistry itself will do.

6) One reason though might be fear of anthropomorphism. But although anthropomorpism is of course a danger here it should be noticed, as Karl Popper observed, that some kinds of anthropomorphism are quite legitimate. This is so

in cases of evolutionary homology, i. e., when similarity between two structures are due to inheritance from a common ancestor. Thus, for instance, since the nose of a dog and the nose of human beings are related through homology Popper finds that such an anthropomorphism is legitimate (Popper 1990) 30). Now, in the case of postulating semiotic competence in animals homology is of course involved, since the prokaryotic cells from which all multicellular life descends already disposes of a very limited repertoir of semiotic competences.