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Causal processes, semiosis, and consciousness

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Abstract
The evolutionary emergence of biological processes in organisms with inner, qualitative aspects has not been explained in any sufficient way by neurobiology, nor by the traditional neo-Darwinian paradigm — natural selection would appear to work just as well on insentient zombies (with the right behavioral input-output relations) as on real sentient animals. In consciousness studies one talks about the 'hard problem' of *qualia*. In this paper I sketch a set of principles about sign action, causality and emergent evolution. On the basis of these principles, I characterize a concept of cause that would allow for a naturalistic explanation of the origin of consciousness. The suggested account of causation also turns the 'hard problem' of *qualia* into the easier problem of relating experimental biology to experiential biology.

1. New approaches to life and consciousness

The past 15 years have witnessed a considerable increase in scientific and philosophical consciousness studies, including research into the material processes related to phenomena of consciousness. This is well reflected in the recent development of cognitive science. Cognitive science studies information processing in the mind in a cross-disciplinary fashion, drawing on research in neuroscience, psychology, logic, and artificial intelligence (especially conceptual modelling based on neural networks). Even though researchers in cognitive science originally did not focus on the study of consciousness, they found they were unable to escape philosophical questions concerning conceptualization, the functioning of symbols, intentionality, reference, and knowledge. In brief, cognitive science found itself saddled with the problem of how to account for the *aboutness* aspect of consciousness—conscious processes (like the processing of symbols and similar intrinsically intentional phenomena) are *about* something, and usually refer to something other than itself. Semioticians have not hesitated to point out that these concepts pertain to *significance*, and thus are located within the sphere of interest of any theory of sign processes.

Later on in the 1990s, 'consciousness studies' established itself as a field of research with separate journals and large conferences. Consciousness studies tries to

overcome the traditional sceptical position of the 'hard' // p. 314 / sciences that one could not deal in any serious theoretical fashion with subjective phenomena—i.e. with phenomena which hitherto were studied only phenomenologically 'from within' (or even by very naive forms of 'introspection'), or by relating data 'from without' of human brain activity (gained by various scanning methods) with the verbal reports of experimental subjects communicating their simultaneous experiences 'from within' of doing different tasks. In the same period, traditional philosophy of mind seemed to 'rediscover' its proper object (Searle 1992) and again became a flourishing area of research. Indeed, philosophy of mind was inspired by cognitive science to state (or reformulate) the so-called 'hard' problem of consciousness (Chalmers 1996). Similarly, cognitive semantics (Lakoff & Johnson 1999) and 'new AI' or new robotics (Ziemke & Sharkey 2001) increased the interest in new conceptions of knowledge and language as phenomena that are always strongly tied to the condition of being realized through a body ('embodied knowledge')—as 'enacted' phenomena in interaction with a surrounding environment in specific situations ('situated cognition') and expressed in sign systems whose meaning is grounded in basic metaphors related to the body and the specific context in which that local agent is embedded.

Furthermore, within the philosophy of biology interest shifted from a narrow focus on problems within a neo-Darwinian conception of evolution towards a more semiotic perspective. Within neo-Darwinism, the evolution of species is taken to be the result of natural selection of the 'fittest' variants of the set of phenotypes (or 'interactors'), themselves being an ontogenetic and molecular product of inherited genotypes (or 'replicators'). The neo-Darwinian paradigm operates with an account of evolution as an algorithmic and mechanist process and due to this fact the emergence of physical systems capable of processing experience and signification remains a deep explanatory problem. From the neo-Darwinian point of view natural selection works on insentient zombies just as well as on sentient animals, provided they have the same behavioral input-output relations and the same functional architecture as sentient animals. The natural history of signification remains unexplained, and it is this lack of explanation, or at least the inconceivability of such a process within a paradigm constrained by a mechanist metaphysics, that biosemiotics seeks to remedy. Biosemiotics[1] does not contend the concrete findings and explanations of neo-Darwinism as a limited scientific

[1] It is beyond the scope of this paper to introduce biosemiotics in any detail. The basic idea of biosemiotics is to consider living systems not so much as organized molecular systems, but rather as semiotic systems (sign processing systems) where the molecular structure functions so as to mediate semiosis, or sign action. During the last decade more and more theoretical biologists have been influenced by biosemiotic ideas. For brief comprehensive introductions, see Hoffmeyer 1996, Emmeche et al. 2002, Kull ed. 2001.

research programme, but questions any assertion as to the completeness of that framework vis-à-vis all aspects of evolutionary processes. As a corrective theoretical enterprise, biosemiotics attempts to contribute to an investigation of those questions that have been dismissed due to the materialist and reductionist assumptions of neo-Darwinism, // p. 315 / such as the question about the emergence of consciousness. Other research areas of theoretical biology—e.g., the new form of interactionism in the evolution-development debate called 'developmental systems theory' (see Oyama et al. 2001) and the transpositions of complexity research in modern biophysics by Stuart Kauffman and others—contribute in parallel other 'missing links' for a more coherent theory of evolution, and serve as additional inspirations for the biosemiotic project. These theoretical developments open up new perspectives on the processes linking consciousness, body, organism, and environment, including the qualitative aspects of consciousness that have been neglected due to traditional metaphysical and methodological presumptions of natural science.

The purpose of this paper is to offer some suggestions about the concept of cause that is needed for a biosemiotic understanding of the origin of consciousness in evolution. This is a much more limited project than trying to sketch any specific theory about the evolutionary emergence of consciousness. Within the current biosemiotic literature there are various vaguely formulated ideas about an alternative concept of cause which could be used to overcome the problem of dualism, and to integrate physical, behavioural, and phenomenological descriptions of the phenomenon of consciousness. Given that semiotics takes its departure from the work of C. S. Peirce, the latter's own—very general—concept of final causation in Nature is an obvious point of departure (Santaella-Braga 1999, Hoffmeyer 2002). However, the Peircean notion of final causation needs to be reassessed in view of the results gained in nearly hundred years of subsequent research in physics, biology, and process philosophy. In particular, I shall here consider the possibility of integrating (a) the understanding of sign action and interpretation within biosemiotics with (b) a special elaboration of the concept of cause from the point of view of non-linear dynamical systems theory and complexity research (see Emmeche 1997 for a brief introduction to this field). Thus, I will investigate if such a refornulated notion of causation derived from biosemiotics and complexity research can contribute to an understanding of the origin of consciousness in evolutionary history.

2.General principles for a natural semiotics of causes.

Consider the following six principles.

1. There are several types of causes.
2. Causes are real on several levels.
3. Signs act in nature and enter into networks of causes. // p. 316/
4. By emergent evolution new types of causes are generated.
5. Causes are associated with levels of signs.
6. The causes within a complex include causes within the components.

I hold that these principles (which are not logically independent—e.g. (5) can be derived from 3. and 4) highlight central aspects of the notion of cause and causation needed in a comprehensive theory of evolutionary history. My main task in this section is to elaborate on these six principles and to try to render them plausible.

1. *The principle of causal pluralism.* Complex things are the outcome of complex processes and thus they have many kinds of causes; effective, organizational, material, semiotic. It is a physicalist presumption that only elementary particles harbour the causal powers of the universe in which we are situated. On the contrary, we must allow that *causes* — by which we mean real powers in nature, in mind, and in society which change things, process information, and develop the richness of phenomena in the world — can have a plurality of characteristics, and that we can achieve an understanding of these by different forms of inquiry. This idea is not new but goes back (although in a substance-metaphysical framework) to Aristotle who distinguished between different types of causes.

2. *The principle of causal realism on several levels*. The causes are located in nature, not merely in our description of nature, and nature has several levels. Physicists talk about the quantum ladder spanning from quanta to atoms, molecules, and so on. Biologists talk about cells, organs, organisms, populations and species. The properties of the phenomena at higher levels cannot normally be reduced to the properties of the entities or processes at the lower levels. A 'thing' or entity at level *n* may have its own causal powers interacting with other entities at that same level. Such entities may be found to be an organized processual product of interacting components belonging to level *n-1* (e.g., an organism, being composed of cells, causes changes in other organisms). The items in what we vaguely call the physical world have causal powers, but the same

applies to phenomena in what we just as vaguely call the psychic[2] world. Also social phenomena like institutions, and abstract entities like numbers and rules of inference, are governed by constraints with causal consequences. In an institution the individuals are constrained by social rules, and in her thoughts the mathematician is constrained by abstract rules, and indeed, even within a cell the molecules are constrained by their functional relations to other molecules defined by the whole causal network of metabolism.[3] A thought can cause the following thought, and in their modes of being that are explorable by science thoughts are associated with (i) biological states in the parts of an organism (especially those parts in the // p. 317 / nervous system that process signs, though not exclusively in the brain), and (ii) the environment of the organism. There is nothing mysterious about conscious and physical phenomena both having causal powers. Apart from the mentioned physicialist bias there is nothing in the concept of a cause that would prohibit assigning causal powers to non-physical items.

3. *The sign principle*. Causes exist in nature, including that very large part of nature that brings about (generates, process and interprets) signs. This is the semiotic account of signs as very general processes, active in nature as well as in mind, which constitute the very precondition for human beings—and living beings in general—to know their worlds, their Umwelten. This approach to signs—versions of which are known since antiquity—received its most comprehensive elaboration in Peirce for whom signs are triadic relations developing in time[4] through an interplay between lawlike tendencies and spontaneous random perturbations, and mediated by an interrelationship to other signs; or, as one may say, through the interplay with historically determined coding systems. Signs are not simply mental or psychic constructions in the figments of individual persons' brains, they are relationally extending within the physical space (so that something physical has to instantiate or realize them); even 'virtual' signs in information technology systems have this 'material' aspect. Yet this 'materialist' aspect of the sign principle does not commit us to physicalist reductionism, as higher order 'spaces' are embedded within, yet irreducible to, the physical space. (The physics cannot be ignored,

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[2] The adjective 'psychic' (and the noun 'psyche') is used here for what we in English just as vaguely call "psychological phenomena" in order to emphasize that it pertains to the psyche as that emergent property of some organisms having an animate, experiential or 'inner' world.

[3] A detailed exposition of the inter-level relations in a living cell can be found in Bruggeman et al (2002), see also Boogerd et al (2002).

[4] One might think that temporally developing relations are not necessarily processes; they may be sequences of states. However, in Peirce's philosophy, *process* is of the nature of Thirdness, i.e., the metaphysical category of mediation, and Peirce considered signs or semiotic processes of interpretation as a temporally continuous developmental phenomenon (in accordance with his synechism, i.e., philosophy of continuity).

of course, since physical laws set limits on the amount of information that can be contained in a limited space defined by some number of atoms, and on how fast signs can be transmitted; physics cannot tell much, however, about the meaning of signs on higher levels of signification.) Furthermore, the reality of signs does not imply any thesis about correspondence or simple isomorphism between the signs of nature and our theoretical knowledge. The semiotic realism of the sign principle is not a claim about simple correspondence between language and reality, or about the truth of a sentence being reducible to its truth-conditions. It is a way to express the reality of the existence of a plenitude of signs in a human universe; the fact that the human universe is filled with signs connecting nature and culture in hybrid ways. Implied in the claim of the reality of signs is that signs have potential or actual causal roles, understood here as a capacity for determination, which is a causal notion broader than efficient causality (cf. Santaella-Braga 1999). This is evident Peirce's definition of a sign. "A Sign, or Representamen, is a First which stands in such a genuine triadic relation to a Second, called its Object, as to be capable of determining a Third, called its Interpretant, to assume the same triadic relation to its Object in which // p. 318 / it stands itself to the same Object" (CP. 2.274). This doctrine of the causal reality of signs has a *principle of symmetry* built in. When we claim that parts of nature create, process, and interpret signs, we can just as well read such a statement as the claim that the signs themselves (in ways that are open to scientific inquiry) generate, turn-over, and interpret natural processes. It is an anthropocentric presupposition exclusively to restrict all agency to human subjects. The signs deal with us, just as much as we deal with the signs.

4. *The principle of emergent evolution*. Throughout the natural history of the universe a continuous 'creative' evolution has taken place; an evolution of new types of systems and process types has appeared on higher levels based upon already existing conditions and simpler components and processes. These levels are described today by the empirical natural and human sciences in a mosaic of stories about, among other things, the splitting of the four physical forces in the early universe and the separation of matter and radiation; the generation of new stars and galaxies and clusters of galaxies; the generation of solar systems with planets with individual geophysical and geomorphologic characteristics; the generation of life in a few 'lucky' places (such as here); the creation of the first multicellular organisms; the rise of animals with mental representations (a new kind of 'inner life'); the arrival of social systems; the emergence of human beings with their language and culture; the generation of states and higher forms of civilization. For

each coming of a new type of system there appear some new properties, processes, patterns and forms of movement, which in comparison with the former types are *emergent* in the following sense. They are (a) radically new, that is, with new properties characterizing the macro-level system rather than its component parts; (b) they are non-predictable from knowledge about the initial conditions and the guiding laws or tendencies; (c) they function as real causal constraints for the component processes that partake in this new whole structure. In (a), 'radically new' typically means 'irreducibility' as applying to (i) irreducibility in principle (*de jure*), *and* (ii) irreducibility in praxis (*de facto*). The generation of new system types and the generation of a causal dynamics that characterizes them are simply two sides of the same coin.

5. *The principle of emergent sign levels*. There are different levels of nature's handling of information, that is, generation of signs, translation, coding, re-coding and interpretation of signs within the organism and in between it and its nascent environment. Sign processes at a certain level (the 'focal' level) can have specific characteristics that cannot by any simple method be deduced from (or reduced to) lower levels of sign processing. Such processes would then be // p. 319 / emergent compared to their parts, which means they have (at least seemingly[5]) irreducible properties. As emergent relational entities, these signs have a real existence, *sui generis*, and partake in a causal network together with other signs on the same focal level. In this world of signs, which is simply the signifying aspect of what normally happens in the material world, there are both continuous transitions and graduations of the intensity[6] of the various meanings, as well as more sudden 'jumps' between levels of signification as in the contrasts between different coding systems (as in any 'semiosic architecture', cf. Taborsky 2002). This dialectics between continuity and borders between levels is not something incomprehensible and is not true only to signs. It can also be seen in simple self-organizing systems. For instance, in oil heated in a frying pan one can see the formation of heat convection cells (drop in some thyme powder or pepper, then it's easy to observe): A singular molecule can be constrained to the middle of a convection cell, or circulate around in the periphery of the cell, and eventually be transported from one cell to its

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[5] The restriction 'seemingly' is due to the fact that even though emergent properties are defined in terms of genuine irreducibility, there may be cases where our claims concerning genuine reducibility may be changed by developments within science.

[6] It may be possible to define *semiosic intensity* precisely, but in the context of the present exposition this concept is only implicitly defined (it be clearer from what I say on the 7th principle below). It connotes (but does not equal) the semantic distinction between intensional and extensional, and the notion of intentionality in philosophy of mind. However, semiosic intensity (or intensity of meaning) is more like a measure of the number of possible experiential qualities of a sign process, and thus of the richness of its interpretation. Thus, it is related to the notion of semiotic freedom in Hoffmeyer (1996).

neighbor as the cells are continuously connected. Yet there are two levels: a level of the continuous liquid of high viscosity constituted by an enormous amount of individual molecules, and a higher level forming the pattern of convection cells, the level that introduces distinctions in the continuum, distinctions of cells, bordering zones, centers, peripheries, ordered directions of movement.[7] The oil that is organized into these 'cells' (which are far from being alive in any biological sense) can be understood as a form of 'proto-semiotics', or physiosemiosis (as sign activity occurs in the non-living chemical and physical realm, "in the background" as it were, "throughout the material realm" (Deely 1990: 30)). Suddenly the different regions of the liquid are ascribed ('objectively' as it were, not due to the ascriptions of an external observer) a new significance, namely, to be center or periphery of this or that cell. Obviously, we get more complicated relationships on higher (bio- as well as glottosemiotic) levels between the emergent meaning of a whole and its component parts, where the parts combine to determine the meaning of the whole, and the whole conversely determine the meaning of the parts. The meaning of a DNA sequence depends, among other things, upon its neighbouring sequences, as the meaning of the individual words in a sentence depends on the meaning of the whole sentence, and in fact on a wider pragmatic context. However, the meaning of the whole is also determined by its parts. The individual DNA sequences co-define an organism (together with an abundance of extra-genetic factors), as the meaning of individual words co-determines the meaning of a sentence. This interplay between wholes and parts is a general organicist principle (cf. Gilbert & Sarkar 2000). // p. 320 /

6. *The principle of inclusion*. The higher levels presuppose and include the lower. Yet knowledge and understanding of the lowest levels presuppose as a rule the higher.[8] The principle of inclusion is important both (A) generally, regarding the emergent levels, and (B) particularly, regarding signs.

(A) With respect to the emergent levels the implication is that the biological includes the physical, even though physics does not fully explain all biological phenomena. A bacterial cell is an organized system of physical processes and doesn't stop being so while unfolding its biotic and semiotic activities; the biological 'laws', habits or regularities governing its metabolism do not in any way break the laws of physics (a

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[7] For a more fine grained analysis of convections cells, see Swenson 1999.

[8] This second, 'upward' direction of inclusion demands a separate treatment, but is not crucial for the argument of the present paper. "Downward" inclusion as, e.g., in (A), a biologic process includes physical processes, and, in (B), arguments including propositions, is primarily an ontological property, while "upward" inclusion is a mixture of epistemic and ontological characteristics; e.g., the laws of physics (not in their ontological sense but in their mode of existence as objects of knowledge) presupposing a knowing inquirer.

vitalist belief in some non-physical life force governing metabolism or the embryologic form-generation is rejected). But this does not imply that physics could specify concepts like "genome", "flagella", "cell wall" or "signal transduction", needed to describe the bacterial way of life. The bacterium is one peculiar way to organize a system of physical processes, and physics cannot fully account for the peculiarities of this organization. There are biological principles (like the cell's regulatory memory encoded in DNA and the overall structure of the cell) governing the physics of a bacterium. We have a parallel situation when we look at the psychic level. The psyche of a human being is an organization of experiential, conscious, and subconscious processes being realized in a biological (and physical) system, but this organization is emergent relative to the biological and the physical. It is in this sense that we should consider psychic processes as included or embedded within biologic processes.

(B) Another important form of inclusion is the semiotic. Sign processes come in various types, and the higher forms include the lower. This insight can be drawn from the classifications (and tri-partitionings) of signs in Peirce's writings. The following talk about sign classification easily evokes the impression that a token of a sign type is a particular entity, which is wrong. However, to re-emphasize, according to the nature of the sign, a particular sign is a triadic relational process (and Peirce was indeed a process thinker). A basic partitioning applies to what the very sign is 'in itself' (i.e., a highly virtual being, apart from its functions as signifying the object and as generating another sign, the interpretant): The sign in itself can be (1) *qualisign*, (2) *sinsign*, or (3) *legisign*. A qualisign is a sign of a mere quality like 'redness'. A sinsign is a singular sign of such a quality, like a token I may experience of particular redness here and now. A legisign is a sign that is a type, like the word 'redness', of which the present text has several tokens (i.e., sinsigns as individual replicas of the legisign 'redness'). In this semiotic context, the principle of inclusion (cf. Liszka 1996) // p. 321 / implies that the higher categories of signs include the lower: The sinsign incudes the qualisign, and the legisign includes the sinsign in the sense that it has to be realized through particular existing sinsigns. Without going into details it should be mentioned that inclusion also applies for the higher trichotomies of signs, that is, the tri-partitioning according to the (similarity-, or referential, or lawlike) relation between the sign and its object, i.e., (a) *icon*, (b) *index* and (c) *symbol* (so that an index includes an aspect of iconicity; a symbol involves an index of some sort); as well as the tri-partitioning according to the sign's relation to the interpretant, i.e., being (I) a *rheme* (a sign which for its interpretant is a word-like sign of qualitative possibility), (II) a

dicisign (a sign which for its interpretant is a proposition-like sign of actual existence), and (III) an *argument* (a sign which, for its interpretant is an inference-like sign of a general regularity, habit or law). Thus the activity of complex signs includes the activity of less complex signs, which means to say that if, for instance, an argument is put forth, this involves the processing of singular propositions and individual words. We return later on to the connection between this principle and its application to emergent levels and to signs.

3. Elements for a theory of the natural history of experience

From the principles set out in the previous section we can begin to catch a glimpse of the contours of an evolutionary theory of the emergence of experience in nature's history. The normative idea of *experimental biology* has for long been one of an objective science based upon the conduct of well-controlled experiments on observable properties of organisms; properties any researcher could access from without as being part of a public sphere of observation. The fact that amimate organisms, including the researcher as a person, always have an 'inner' experiential sphere—we experience phenomena in a way that has an intrinsic qualitative value—was not thought to have any role in the idea of biology after Darwin. Yet this aspect of life, the subject of what we could call *experiential biology*, cannot (or at least not without great difficulty) be accounted for by means of the 'objective' methods of science. Some philosophers talk about 'qualia' to denote the special subjective character of experiences: the fact that roses (or the molecules they emit?) have this particular attractive scent; and that a wet dog has a distinctive other scent; or that light of a wave length of 600 nanometer is experienced as the colour quality of orange.

Questions such as "how do particular properties of the physical acquire particular irreducible experiential qualities?", or "what is the causal // p. 322 / connection between the physical universe and our subjective experience?", are often perceived as old and unsolvable philosophical conundrums. The idea that a handful of principles like the above mentioned should enable us to solve such questions may sound rather far-fetched. Yet let us inspect for a moment an early proposal to this effect: that of Uexkull's. A biosemiotic pioneer, baron Jakob von Uexküll already tried something similar a long time ago by founding what he called "Umwelt-research", i.e. research into the subjective Umwelten of animals, the Umwelt being the subjective aspect of the world experienced by the organism

(Emmeche 1990, Kull 2001). However, the conservative baron would not have embraced the 4th principle as he did not like the theory of evolution. One of the advantages of biosemiotics in its contemporary form, apart from its basic evolutionism, is that it does not force upon us a dualist metaphysics that separates the phenomena into two distinct worlds or realms which are afterwards difficult to connect again. Peirce, to booth, was a monist—he did not believe in the existence of radically different ontological domains or 'types of substances' and developed his own form of process thinking (Rescher 1996). His monism was semiotic, and conjoined with an ontological category theory, based on the categories of firstness (possibility), secondness (existence), and thirdness (reality). The third category includes phenomena of a lawlike nature; processes; the generation of habits, and semiotic phenomena.[9] Let us see how we can use some of the conceptual building blocks of the Peircean system in contemporary thinking about life and consciousness.

The leading idea is to construe the appearance of consciousness in evolution as a process that in many ways resembles the emergence of other complex systems on higher levels — and here we can draw on insights from biology, complexity research and cognitive science — but without tying the description to a physicalist and objectivist ontology (implied by many contributions from the mentioned areas) that allows us to account only for the world's 'outer' or behavioral properties. From the outset we will acknowledge that some complex systems (as for instance animals) may have emergent phenomenal properties which are only directly accessible from within those very systems themselves, yet such phenomenal properties being no less real than behavioural properties accessible to public observers. This assumption needs to be backed up by Peircean semiotics (seeing signs in organisms as including qualitative experiential aspects) as embedding theoretical framework. As John Searle (1992: 97ff) pointed out, the standard model of observation for natural science—presupposing a clear distinction drawn between a subjective observer and the object observed—breaks down in the case of consciousness. This distinction, and // p. 323 / the model of scientific observation that rests on it, do not hold for consciousness because of its specific mode of being real, i.e., because of it being at once observer and observed. The traditional model of observation is a basic obstacle to a biological understanding of consciousness (a conclusion Searle was not ready to draw). Even an understanding of complex processes of living systems other than consciousness

[9] "By the third, I mean the medium or connecting bond between the absolute first and last. The beginning is first, the end second, the middle third" (...) "Continuity represents Thirdness almost to perfection. Every process comes under that head", Peirce (CP. 1.337).

demands multiple, inner as well as outer, perspectives (Van de Vijver et al. 2003). Thus there are good reasons to include the semiotic approach as a fully valid method on a par with traditional 'objective' methods, in particular—but not exclusively—in order to account for direct conscious experiences. The idea about signs, or sign action, as genuine and real processes with qualitative aspects is an important key to an alternative research framework in consciousness studies—and a key to an alternative philosophy of science with a broader view of what the set of acceptable methods may comprise.

Let me begin with a brief explanation of how the generation of a complex system affects its parts. In a sense, we are dealing here with the "mind over matter" formula, though purged of any spiritistic mysticism and dualism. There is nothing mysterious about a pattern having the power to govern its parts. The cell-like or beehive-like patterns that emerge in a process of self-organizing convection cells on a frying pan will to a large extent determine the trajectories of the individual molecules. After the initiation of the self-organization of the pattern of convection cells, the movements of the molecules are constrained by the pattern (cf. Swenson 1999). A lipid molecule in the oil cannot any longer move around by random diffusion (as in a liquid where the molecules realize Brownian random motion), but is now forced into an emergent pattern of movement. This is what the notion of 'downward causation' implies, a modern form of the Aristotelian idea of a final cause (Emmeche et al. 2000). The form (pattern, or mode) of movement constitutes a higher level which constrains or 'governs' the movements of the entities at the lower level. Complex systems studies within physics is rich in examples of this kind, and once one is familiar with this way of conceiving causality, form, and interactions between levels, one hardly finds cases in biology where this principle is not at work, as biosystems intrinsically involve several levels of causality. (One may even consider the influence of such a paradigmatic idea upon our capacity to identify individual empirical cases as a further example of downward causation). A certain species in an ecosystem has to adapt continuously to fluctuations in climate, nutrients, competitive interactions with other species, and so forth, but if a species is decimated or even driven to extinction by a competitor, this does not necessarily have to change the overall dynamics of an ecosystem; a new species // p. 324 / may simply take-over and occupy almost the same niche as the former (Ulanowicz 1997). Thus, there are structures in the ecosystem, e.g., in food webs, that allow particular elements to be substituted and define criteria for their remaining in the system, and in that way constrain the possible trajectories of evolution for the elements of the system. In a similar way, an enzyme

within a cell cannot chemically do all kinds of reactions whatsoever, but is functionally bound to realize very specific catalytic processes; thus one may conceive of function as the active ascription of significance by the whole to the individual biological parts (Emmeche 2002).

Downward causation is a form category of cause that must not be confused with the time-sequential 'effective' cause. The renaissance critique of the Aristotelian variant of the principle of causal pluralism left one single type of cause as the only legitimate candidate for use in causal explanations: the effective cause, interpreted as sequential in time, "if A (cause) now, then B (effect) thereafter". In contrast, downward causation 'from' the emergent level 'to' the individual parts of the system is not something to be understood as being extended in sequential time; it is rather the form of movement (through 'phase space') which the whole system forces upon the individual elements. The analysis of the physics of complex systems offer some good analogies for an understanding of this kind of structural causation. From the physical point of view, phase space is structured; it contains regions of specific types of attractors (e.g., point attractors, cyclical attractors, 'strange' or chaotic attractors) who delimit the possibilities that a system in its movement through phase space may choose, even when 'choices' are real (as in bifurcations). Even though such analogies most often can be drawn only in a loose and metaphorical fashion, it is still possible to achieve a schematic understanding of conscious processes — e.g., the visual consciousness of a prey animal and its pragmatic decisions inferred from the percepts of a predator — by considering such processes as a system's movement through an abstract space of possible brain states. This abstract space is a phase space with certain attractors that govern the activity of local clusters of neurons (within a certain range of variation determined by random processes). In such a 'weak' version of downward causation (Emmeche et al. 2000) consciousness manifests itself as a pattern governing the behaviour of the individual neurons or neuron cluster. In fact, consciousness can be perceived as a form of movement at a high level that is co-determining the behaviour at the micro-level of the individual cells and molecules in an organism and its surroundings. In other words, the idea is to use a dynamical approach to cognition (cf. Skarda & Freeman 1987; Port & van Gelder 1995; see // p. 325 / also Newman 2001) but without eliminating or reducing the qualitative aspects of the phenomena of consciousness.

4. Consciousness and experience

It may sound bizarre to treat self-organizing heat convection cells on a frying pan as something that should have any bearing upon our understanding of consciousness, but the basic idea is not some form of panpsychism, according to which consciousness should be found--though of very low intensity--even in such a simple and purely physical system. What is expected to be found in lower intensities are specific sign processes, that is, signs producing and mediating other signs. Consciousness is, in contrast, an emergent phenomenon, associated with particular forms of sign action in particular kinds of systems: self-moving autonomous organisms—animals. The concept of experience describes the continuous scale between very simple and very complex forms of sign activity. The concept of consciousness describes a jump in this continuum. *Experiences* — understood as traces of particular significant interactions between a system and its surroundings that for some period is represented within the system — exist as coded even in pure physical systems (like moon craters who indexically 'encode' earlier meteor impacts), although it is only with animals as a system type that the full implications of this concept is unfolded. By drawing suitable distinctions in types of semiotic processes we may be able to settle the controversy between, on the one hand, a 'crude' pansemiotics claiming that every phenomenon in the universe is a sign (which is hardly true since both pure chance and the brute facticity of here-and-now — in Peirce's terms, phenomena that are instances of the categories firstness and secondness — are not yet semiotic), and on the other hand, a restrictive variety of biosemiotics, claiming any semiotic activity to be co-extensive with biological activity, that is, that one should not be able to conceive of sign processes before the advent of life on Earth. I suggest that we avoid both alternatives and rather work up clear distinctions between semiotic processes in physical, biological and psychic systems, and thus conceive of the formation of experience as a fundamental requirement for the particular type of semiosis that during the course of evolution is intensified as consciousness.

In other words, I want to promote the thesis that there are comparable semiotic processes at the physical and biological level. Our contemporary physical universe with it characteristic chemical elements is a particular way of 'coding' the energy of the universe (Christiansen 2002, Taborsky 2002) — i.e., this energy is not dispersed in a big undifferentiated porridge, but is exactly // p. 326 / differentiated into matter and radiation (a difference that really makes a difference), and matter again is differentiated into the well-

known elements (the periodic table being our rational symbol of the universe's own coding of the elementary particles into different kinds of atoms). Similarly, biological phenomena are a particular way of 'coding' organic chemistry. The organisms are not dispersed into a big undifferentiated porridge of macromolecules (lipids, proteins, nucleic acids, carbohydrates etc.); these substances are coded into the particular autocatalytic system of the cell with its network of biomolecular signs, which continuously maintain both the network and its boundary, the cell membrane. The evolutionary experiences acquired by the cell line's natural history are coded partly in the form of sequence information in DNA, and partly in the whole complex structure that a 'modern' (pro- or eukaryotic) cell embodies. If we move further up some levels of organization, to animals with nervous systems, we can observe in a similar manner that new, psychic, processes (processes like proprioception, movement, motor coordination, action, perception, attention, consciousness) do not simply constitute an undifferentiated continuum of signs, information processes, or 'computations', but are organized into emergent structures, in which the animal's experiences with its surrounding milieu are continuously transformed, re-built, confirmed, encountered, felt, challenged, re-interpreted, and which forms a rich (emotive, volitive and cognitive) structure of feelings, desires and thoughts; something genuinely semiotic and crucial for the continuation of life of the organism.

Let us take a closer look upon the generation of the specific form of signs we called experiences, within a macro-evolutionary perspective.[10] We can do so by formulating a new principle, closely connected to the earlier ones:

In macro-evolution experiences are intensified from movement to consciousness. The idea is (a) to relate consciousness to certain especially salient 'jumps' (or instances of emergence) seen in physical and biological evolution, primarily the transition from 'plants' (loosely conceived) to animals i.e. from multicellular organisms with no nervous system to those with nervous system; and (b) to relate this jump to a leap within the semiotic aspect of the same macro process—from experiences as simply past-directed and fossil-like signs, to active, sensing, feeling, and future-directed signs (i.e. intentions, as intentionality is often a directedness towards possible future state of affairs not yet realized). Let us call this:

7. *The principle of semiotic intensification*. Signs are found at the physical, the biological as well as the psychic level, and the same applies to experiences (broadly construed as here). Experiences are // p. 327 / fossilized signs (cf. Hansen 2000) or quasi-

stable forms of movement that organize the system's past forms of movement in such a way as to have significant consequences for the system's future movement. As signifying they are triadic by nature and thus involve (i) the physical carrier of 'the fossil' (the representamen), (ii) its reference to its significance (the object), and (iii) its potential or actual future-directed effects (the interpretant(s)). The intensification of the sign process takes place at several levels, it is at once physical, biological and psychic (see below). With the emergence of coded autocatalytic life on cell form, the semiotic freedom[11] is intensified at the biological level. Here semiotic intensification manifests itself both by the appearance of qualitative irritability[12] (in cells who selectively can respond to stimuli) and by the emergence of code-duality in the form of cell-lines (with a digital as well as an analog aspect, cf. Hoffmeyer 1996) incorporating past experiences into the future. This semiotic freedom is greatly expanded later on with the neurally based forms of sign action we observe with the arrival of animals. Intensification is to be understood both as qualitative and quantitative. One might conceive of measuring the informational band of an instance of semiotic processing such as cognition in chimpanzees and attempt to operationalize this as information transmission per time unit in the brain modules where the processing is going on. But apart from the theoretical and methodological problems that would be generated by this endeavour, such a quantitative measure does not catch the qualitative and content-related aspects of this kind of sign action. Yet we seldom doubt that a chimpanzee experiences a content of its sensing or perceptual 'measuring' the environment. The idea of semiotic intensification is an attempt to make explicit the intuition that animals experience their world with greater depth and diversification of content than plants, and that something similar applies when we compare elephants to flatworms, or grown-up animals to embryos (fully acknowledging the fundamental difficulties involved in these kinds of comparisons). In a very general sense of the word *experience* one can say that all these systems, even the purely physical, *experience* something, get 'irritated' or affected by their surroundings, and store this influence, even when such stimuli are quite evanescent or produced by chance. In that generalized sense, *process* and experience are interrelated in all situations where the process of interaction

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[10] *Micro-evolution* designates evolutionary processes within a species while *macro-evolution* comprises processes like speciation, generation of longer trends and overall patterns of form relationships in evolution.

[11] Semiotic freedom can be thought upon as a generative combinatorics of significations, see Hoffmeyer 1996.

[12] The term irritability, denoting the capacity of certain parts of the body to contract when stimulated, was introduced by the English physician Francis Glisson (*c* 1597-1677) who saw it as a property of all the body's fibres independent of consciousness and the nervous system (cf. Lawrence 1981). It has played an important role in debate between mechanicists and vitalists over the basic definition of life.

beteween one subsystem (corresponding to an agent) and another subsystem (corresponding to the environment of the agent) leaves traces in one of the subsystems. But only in complex living systems (showing history, multiple levels, and built-in genetic, neural, or psychic mechanisms of selection as an element of the coding processes or memory) the formation of experience has been able // p. 328 / to achieve an intensified form that makes it reach forward in time. This renders such a system anticipatory, i.e., endows it with the capacity of operating with models of possible future states, including what has been called 'mental models'. Such models have both a formal outer aspect (as when a neural code within the visual cortex can be described by scientists as algorithms for edge detection, object recognition, etc.), and an aspect of being amenable to sensory experience from within the system (being able to be sensed as colours, smells, sounds, touches and so on). Thus experiences can be described both objectively in terms of (grammatical) third person predicates, as when we investigate Peter's or the chimpanzee's mental model of a banana, and subjectively in the form of descriptions of the grammatical first person, giving others indirect access to one's own phenomenological experience of a banana tree.

In a physical system like a tornado (an open, metastable, dissipative, self-organized system) there is no marked distance between outer and inner, nor between past and future. Talking about a tornado's spatial differentiation into 'eye' and 'body' is not meant to imply any truths about a rich experiential life of tornados. For the tornado, there is little separation between a reference of the experience to the conditions that makes the same experience possible, the processes it realizes, and its immediate occurrence. The movement is hardly evolutionary, there is no difference between the units of selection and the unit of evolution; everything in the system is being 'selected' for continuing self-organizing movement given that the boundary conditions for such a type of movement of system are satisfied. The movement is identical to a simple time evolution of the system.[13] (This is why moon craters as traces of experience have a different status relative to us and relative to the moon, which is an important distinction for us 'moderns' who have no empathy with the scarred man in the moon).

In biological systems like the cell, experiences are, among other things, the genetic 'fossils' in DNA witnessing the specific proteins that were functionally participating in earlier ancestor cell lines to maintain the metabolic form of movement. Here, a high degree of temporal separation of past movement and present structure is achieved. This is due to the fact that the digital code provides stable representations of, for instance, early active

but now passive genes (so-called 'pseudogenes' which have had immediate significance, but now only have potential significance for the cell life or the species as a ressource of variation and mutation). In addition, the system's boundary to its environment is sharper and functionally effective. The cell membrane represents the organismic information about a primary difference between 'inner' and 'outer' which intensifies the significance of // p. 329 / molecular systems for measuring changes in what is 'outer' in relation to the states of the 'inner'. The constant threat of the draining of energy reserves (and thus of death) constitutes a *telos* within the system, that is, the goal of survival, a need, an overall interpretant corresponding to the future dual possibility of death or continuing life of the system. Each of these two possibilities, life or death, organize the developmental trajectories of the elements of the system around a particular attractor, of which only one, life, has a biological description in addition to the purely physical one. (The physical description of the phase space, allowing for statistical measures, has to be supplied with a 'an additional' biological or quasi-semiotic description of (minimally) a historically contingent 'sequence space' of digital codes, cf. Küppers 1992). This goal or need of survival, which already appears to emerge for free-living single cell organisms (simply constituting a continuous line of cell divisions) receives more complicated elaborations, both by the exchange of fragments of experience between the cells (e,g, by bacterial conjugation DNA plasmids can be transferred from one cell to another, a kind of sex), and by the generation of multicellular organisms with life cycle, alternation of generations and sexual reproduction, i.e., species in a 'modern' sense.

In a psychic (and thereby biological) system like a multicellular animal, experiences are sign processes that temporarily 'fossilize' as quasi-stable representations of outer forms and their relations to the organism and its inner, and thereby create traces in the form of neurally stored patterns of memory. Through the evolution of multicellular organisms, especially of animals with a nervous system, an additional intensification is achieved—partly by irritability[14] (which gets differentiated into neurally based systems of representation with outer as well as inner aspects), and partly by sign based strategies

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[13] This is compatible with a physical (and trivial) sense of 'time evolution' in which no reference to specific biological phenomena like natural selection based upon variation and inheritance is implied.

[14] Cf. footnote 12 on irritability. It is useful to remember that Peirce (in his 1890 manuscript "A Guess at the Riddle") viewed the irritability of the "protoplasm" as an example of Firstness: "The properties of protoplasm are enumerated as follows: contractility, irritability, automatism, nutrition, metabolism, respiration, and reproduction; but these can all be summed up under the heads of sensibility, motion, and growth. These three properties are respectively first, second, and third." (CP.1.393). Here, the phenomenal aspect of irritability (or sensibility), as a first, can be seen to correspond to the phenomenal aspect of very simple forms of signs, the qualisigns (see below). Thus, we can conceive of simple irritability as already

for reproduction and ecological 'competencies' (such as food search patterns). The semiotic intensification transforms merely vegetative organisms into animals, that is, it endows them with dynamic forms — corresponding to what Aristotle[15] called a soul of movement — i.e., semiosic active systems, that through self-movement acquire experiences, cognitively process these, and have an emergent phenomenal inner world. Movement includes autonomously governed changes of form and position of parts of the organism (like muscles) based upon sign processes like proprioception and sensori-motor coordination. Movement must be distinguished from merely physical change of position over time; rather, the course of movement in animals is always governed by semiotic codes based within the animal body (an idea elaborated in detail by Hoffmeyer 2000, and Sheets-Johnstone 1998). Movement is a process which is externally observable as well as internally sensed. In simple animals the // p. 330 / movement-governing models are identical to the immediate coordination of sensory signs from the environment and proprioceptive signs of the body, signifying states and movements of the muscles. Thereby an *Umwelt* is formed as functional circles which dynamically represent flexible interactions between the animal and its environment, i.e., a species-specific 'cut'—mediated by the sensory organs—of relevant features of the organism's physical environment is formed. The simple kinds of experiences generated in this process can later on (in animals with more elaborated systems for neural representation) be incorporated as a source for higher-order anticipatory models, not only including here-and-now coordination of movement, but also longer sequences of movement, based upon 'choice' among (or inference to the best consequences of) several possible routes of escape, or other kinds of action. Such models are symbolic in form to the extent that the experiences govern the relevant inferences in a law-like manner. (We shall not discuss the relevant concept of symbol here, but see Stjernfelt 2001).

Consciousness appears as the present moment's qualitative feature of a moving animal which experiences a process of complex relations between sensing the movements of its own body and sensing the corresponding changes of the environment. Consciousness is an emergent higher order patters which (i) has genuine causal power in its own right (just like the movement patterns that are based upon experiences and govern

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having outer, behavioural aspects (like a capacity to contract responsively upon a stimulus) as well as inner aspects (feeling, pain, itching).

[15] Compare Aristotle's biologically based psychology in *De Anima* (see for instance Everson 1995). No need to say that the purpose here is not to give an exposition of the hierarchic system of 'souls' in Aristotle, but to let his system inspire the interpretation of what has been called here the semiotic intensification as an evolutionary process. On the combination of Aristotle and biosemiotics, see also Brogaard (1999).

the behavior of the organism) and (ii) has a qualitative, phenomenal aspect (just like irritability). I cannot go here into details on the neurobiology of memory, proprioception and perception, or the electrochemically based processing of information in the nervous system. But it is possible to conceive of consciousness as a specific property of the dynamical interpretation of experiences, and of experiences of experiences, including proprioception; this interpretation is an ongoing affair, continously modulated against the habit-like traces that earlier experiences have deposited in the neural codes of the body. Like any sign, consciousness is a dynamic, relational, and intentional phenomenon; consciousness connects signs outside to signs inside the organism—consciousness is nothing in itself, it emerges only in connection with the general semiosic make-up of the experiences of the body.[16] The subjective nature of experience is rooted in a semiotic intensification of those qualisigns that are parts of the subjective aspects of irritability (and 'appetite', see Brogaard 1999) that are found in even simple organisms. The signs themselves have both formal outer aspects allowing us to re-represent them as an algorithm or a logic model, but // p. 331 / their formalization does not exhaust their qualia character. Normally this character is shadowed by their dynamical and formal aspects, but it can be observed in direct immediate experience. This means that semiotics as a set of methods must include not only the construction of empirically testable models of dynamic and formal aspects of consciousness (as it is already done to a large extent within cognitive science) but also phenomenological approaches to the qualitative experiential processes connected to sign action. The situation calls for a *qualitative organicism* (Emmeche 2001), according to which complex systems are both emergent and capably of supporting phenomenal experience. They are considered as emergent patterns of movement with downward causality (in the sense mentioned above in which the emergent pattern of movement organizes the dynamics of the parts through new boundary conditions for their unfolding). In addition to this, complex systems as exemplified by animal bodies are also taken to realize phenomena such as telos, semiotic intentionality (cf. Peirce's notion of 'final causation') and experience formation within an Umwelt. The phenomenal aspect of sign interpretation is simply the experienced quality, the inner side

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[16] Describing consciousness as being nothing in itself and only understandable as a situational, relational and embodied phenomenon, may seem to contradict my claim above that consciousness is "an emergent higher order pattern with a genuine causal power in its own right", yet, this discussion can only be clarified within a general treatment of the nature of emergence and downward causation (see, e.g., Emmeche et al., 2000). The fact that an item is a higher order phenomenon, such as a mental image, and has a causal power *sui generis*, does allow for the possibility that the item is also essentially dependent upon its constituent parts and processes and its (semiotic and material) relations to its environment.

of those transformations in the neural state space that are generated with this higher form of semiosis.

Thus a new concept of *qualitative complexity* is abducted: A system of processes is qualitative complex if (i) the system is self-organizing and has emergent properties and downward causality, (ii) the system has an Umwelt—the subjective aspect of the world experienced by the organism—giving rise to experience-based qualia (such qualia having the character of qualisigns as defined above), (iii) these qualia have causal efficacy (not in the sense of efficient causation but as a form of final causation). Merely epiphenomenal interpretations of qualia are accordingly excluded—for certain aspects of the system the fulfillment of criterion (ii) is a a necessary condition for fulfilling criterion (i).

In other words, an externalist description of the motion (changes of spatial positions) of an animal within an environment is not sufficient for understanding the specific animate, flexible and graceful form of movement governed by an interactive experiential Umwelt. Within the Umwelt's embodied process of experiential becoming (incorporating a phenomenal dimension grounded in the qualisigns included in the system's semiosis), consciousness emerges a causally consequential form of orchestrating (by downward causation) the correlative 'self' of the system, making it cohere and giving the movement its 'animate form'.

This is of course an insufficient sketch of the causal principles that must be taken into account in a future processual and biosemiotic theory of consciousness, yet I hope the vague approximation to such principles // p. 332 / I have offered here suffices to outline the project. To restate, we have the following principles that may be used to formulate a more detailed theory about the emergence of conscious processes in evolution: (1) There are several types of causes, and one can see consciousness and mental signs as quasi-autonomous formal and final causes that are active within the complete system of an animal in its surroundings. (2) The causes are active at several levels and one can consider the psychic as the level for conscious sign action (this level also include non-conscious signs). (3) Signs act in nature and enter into networks of causes; within the body conscious signs enter together with other signs in causal networks. (4) By emergent evolution new types of causes arise, and experience-based movement in animals is such a type. (5) Causes are related to sign levels, and have, like the signs themselves, an outer as well as an inner side. (6) Causes in complex phenomena include causes in simple phenomena; and causes that regulate consciousness include causes regulating physical and biological processes in the animal as well as sign processes related to sensing and

irritability. (7) In the course of macro-evolution experiences get intensified from movement to consciousness, and one can conceive of consciousness as the experiential aspects of sign processing (production, coding and interpretation of signs) in self-moving systems. (8) Consciousness is the present qualitative moment of a continuously running future-directed experiential process.

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References // p. 334 /

Baas, Nils A. and Claus Emmeche (1997): "On emergence and explanation" *Intellectica* 1997/2, nº 25, p. 67-83.

Boogerd, Fred, Frank Buggeman, Cathjolin Jonker, Huib Looren de Jong, Allard Tamminga, Jan Treuer, Hans Westerhoff & Wouter Wijngaards (2002): "Inter-level relations in computer science, biology, and psychology", *Philosophical Psychology* 15 (4): 463-471.

Brogaard, Berit O. (1999): "An Aristotelian approach to animal behavior", *Semiotica* 127 (1/4): 199-213.

Bruggeman, F.J.; H.V. Westerhoff & F.C. Boogerd (2002): "BioComplexity: a pluralist research strategy is necessary for a mechanistic explanation of the 'living' state", *Philosophical Psychology* 15 (4): 411-440.

Chalmers, David (1996): *The conscious mind. In search of a fundamental theory.* Oxford: Oxford University Press.

Christiansen, Peder Voetmann (2002): "Habit formation as symmetry breaking in the early universe", *Sign Systems Studies* 30(1): 347-360.

Deely, John (1990): *Basics of Semiotics*. Bloomington: Indiana University Press.

Emmeche, Claus (1990): "Kognition og omverden - om Jakob von Uexküll og hans bidrag til kognitionsforskningen", *Almen Semiotik* 2: 53-67.

Emmeche, C. (1997): "Aspects of Complexity in Life and Science", *Philosophica* 59 (1): 41-68. (www.nbi.dk/~emmeche/cePubl/97g.complisci.html)

Emmeche, C. (2001): "Does a robot have an Umwelt? Reflections on the qualitative biosemiotics of Jakob von Uexküll", *Semiotica* 134 (1/4): 653-693.

Emmeche, C. (2002): "The chicken and the Orphean egg: On the function of meaning and the meaning of function", *Sign Systems Studies* 30(1): 15-32

Emmeche, C., F. Stjernfelt & S. Køppe (2000): "Levels, Emergence, and Three Versions of Downward Causation", p. 13-34 in: P.B. Andersen, C. Emmeche, N.O. Finnemann and P.V. Christiansen (ed.): *Downward Causation. Minds, Bodies and Matter.* Aarhus: Aarhus University Press.

Emmeche, Claus; Kalevi Kull and Frederik Stjernfelt (2002): *Reading Hoffmeyer, rethinking biology*. (Tartu Semiotics Library 3). Tartu: Tartu University Press. // p. 335 /

Everson, Stephen (1995): "Psychology", p.168-194 in: Jonathan Barnes, ed.: *The*

Cambridge Companion to Aristotle. Cambridge: Cambridge University Pess.
Gilbert, Scott F. & Sahotra Sarkar (2000): "Embracing complexity: Organicism for the 21st Century", *Developmental Dynamics* 219: 1-9.
Hansen, Jens Morten (2000): *Stregen i sandet, bølgen på vandet. Stenos teori om naturens sprog og erkendelsens grænser*. København: Fremad.
Hoffmeyer, Jesper (1996): *Signs of Meaning in the Universe*. Bloomington: Indiana University Press.
Hoffmeyer, Jesper (2000): "The biology of signification", *Perspectives in Biology and Medicine* 43(2): 252-268.
Hoffmeyer, Jesper (2002). Biosemiosis som årsagsbegreb. *Kritik* nr. 155/156, s.101-119.
Kauffman, Stuart (1993): *The Origins of Order. Self-organization and selection in evolution.* Oxford: Oxford University Press.
Kull, Kalevi, ed. (2001): "Jakob von Uexküll: a paradigm for biology and semiotics" (special issue), *Semiotica* 134 (1/4): 1-828.
Küppers, B.-O. (1992): "Understanding complexity", p. 241-256 in A. Beckermann, H. Flohr and J. Kim, eds.: *Emergence or Reduction? Essays on the Prospects of Nonreductive Physicalism*. Berlin & New York: Walter de Gruyter.
Lakoff, George and Mark Johnson (1998): *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought*. New York: Basic Books.
Lawrence, Christopher J. (1981): "irritability/sensibility", p.214 in: W.F. Bynum, E.J.Browne & Roy Porter, eds. (1981): *Macmillan Dictionary of the History of Science*. London: Macmillan Press.
Liszka, James Jakób (1996): *A general introduction to the semeiotic of Charles Sanders Peirce.* Bloomington: Indiana University Press.
Newman, David V. (2001): "Chaos, Emergence, and the Mind-Body Problem", *The Australasian Journal of Philosophy* 79 (2): 180-196.
Oyama, Susan, Paul E. Griffiths & Russell D. Gray (2001): "Introduction: What is Developmental Systems Theory", pp. 1-11 in: Susan Oyama, Paul E. Griffiths & Russell D. Gray (eds.): Cycles of Contingency. Developmental Systems and Evolution. Cambridge, Mass.: The MIT Press.
Peirce, Charles Sanders 1931–58. *Collected Papers of Charles Sanders Peirce*. Vol. 1–6, Charles Hartshorne and Paul Weiss (eds.); vols. 7-8, Arthur W. Burks (ed.). Cambridge, Mass.: Harvard University Press. [References: CP, followed by vol., and paragraph number].
Port, Robert F. & Timothy van Gelder, eds. (1995): *Mind as Motion. Explorations in the Dynamics of Cognition*. Cambridge, Mass.: MIT Press.
Rescher, N. (1996): *Process Metaphysics. An introduction to Process Philosophy.* New York: State University of New York Press.
Skarda, Christine A. and Walter J. Freeman (1987): "How brains make chaos to make sense of the world", *Behavioural and Brain Sciences* 10: 161-195.
Santaella-Braga, Lucia 1999. "A new causality for understanding the living", *Semiotica* 127 (1/4): 497–519.
Sheets-Johnstone, Maxine (1998): "Consciousness: A natural history", *Journal of Consciousness Studies* 5(3): 260–294.
Searle, John (1992): *The Rediscovery of the Mind*. Cambridge, Mass.: The MIT Press.
Stjernfelt, Frederik (2001): "Biology, abstraction, schemata", p. 341-361 in: Berit Brogaard & Barry Smith (eds.): *Rationality and Irrationality*. Vienna: Hölder-Pichler.
// p. 336 /
Swenson, Rod (1999): "Epistemic ordering and the development of space-time: Intentionality as a universal entailmant", *Semiotica* 127 (1/4): 567-597.
Taborsky, Edwina (2002): "Energy and evolutionary semiosis", *Sign Systems Studies* 30(1): 361-381.

Ulanowicz, Robert E. (1997): *Ecology, the Ascendent Perspective* (Complexity in Ecological Systems Series). New York: Columbia University Press.

Van de Vijver, Gertrudis; Linda Van Speybroeck and Windy Vandevyvere (2003): "Reflecting on complexity of biological systems: Kant and beyond?", *Acta Biotheoretica* 51: 101-140

Ziemke, Tom and Noel E. Sharkey (2001): "A stroll through the worlds of robots and animals: Applying Jakob von Uexküll's theory of meaning to adaptive robots and artificial life", *Semiotica* 134 (1/4): 701-746.