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Origin of Species by Natural Translation

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THE INTENTIONAL DYNAMICS OF LIFE

The title of this article obviously paraphrases the title of Charles Darwin's original work from 1859: "On the Origin of Species by Means of Natural Selection" (Darwin 1937 [1859]). My title also implies essentially the same semantic challenge, as did Darwin's title: How can a selection be thought of as natural? And how can a translation be thought of as natural? In the case of natural selection Darwin was most anxious to point out that contrary to artificial selection natural selection did not presuppose the presence of any personal selector. Natural selection was to be understood as a process of selection without a breeder. Contrary to Darwin, however, I shall do no attempt at ridding myself of any trace of intentionality in the process (Hoffmeyer 1996 a). Natural translation is not a macro-level process but a process, which is played out by individual entities at many levels from single cells to organisms or even populations and perhaps ecosystems.

To this day Darwinists have claimed that natural selection rests on purely hypothetical-deductive principles: Suppose a population of organisms reproduce to exceed its resource base. Suppose furthermore that heritable variants exist among individuals of the population. Then competition necessarily ensues and results in better adapted variants leaving more surviving offspring, i.e. in differential survival.

Having thus summarized the hypothetical-deductive structure of natural selection Darwinists often proceed to claim empirical confirmation for the principle by pointing to e.g. the much broadcasted example of British moths gradually attaining a darker coloration in response to growing pollution. As tree stems or telephone poles became increasingly sooted up mutant moths with darker coloration presumably became better protected from birds catching them and such mutants thus expectedly would be favored by selection, which was confirmed by empirical reports.

I shall not here reject the claim for empirical evidence although it should be observed that conflating wing coloration with the origin of a new species is certainly a far jump. Speciation events are supposed to be rare and to depend on much more comprehensive changes, involving e.g. the creation of delicate isolating mechanisms to prevent crossbreeding between individuals from the new and the old species.

Following ecological psychologist Rod Swenson I shall here advance a more profound attack on the received view of natural selection (Swenson 1999). Swenson's point is that intentionality is neither explained nor explained away by the principle of natural selection, for intentionality is tacitly presupposed for natural selection to take place. Intentionality sneaks into the theory via the "principle of fecundity" i.e. the supposed tendency of populations to produce a surplus of organisms relative to the resource base: without fecundity no surplus production, and without surplus no competition and thus no selection. But where does this fecundity come from? Listen to Darwin's own charming prose: Natural selection, says Darwin, follows from a population of replicating or reproducing entities with heritable variation "striving to seize on every unoccupied space in the economy of nature" (Darwin 1937 [1859], 152). Darwin, apparently, did not feel uncomfortable about the idea that a kind of "striving" is inherent to organic life. But this idea "refers precisely to the intentional dynamics of living things...Darwinian theory begs a theory of intentionality; it does not, and cannot, by its own definition provide one" (Swenson 1999).

Swenson proceeds to explain how such a theory of intentionality may be based in a radical reinterpretation of modern (post-Prigoginean) thermodynamics. Central to

this attempt is Swenson's claim that our universe has a deep in-built tendency not only towards increasing its entropy (as stated by the 2. law of thermodynamics) but to do this at the fastest possible rate, which he has called the "law of maximum entropy production" (Swenson 1989). According to this principle thermodynamic fields will behave in such a fashion as to get to the final state - minimize the field potential or maximize the entropy - at the fastest possible rate given the constraints. Somewhat paradoxical perhaps, it appears that the best way to produce entropy as fast as possible is by producing order as fast as possible: Every time an ordered state is produced in a system, implying a lowering of the entropy at that location, there must be produced even more entropy at other locations in the world in order to obey the thermodynamic dictate to always increase the total entropy in the universe.

Swenson and Turvey go to great detail in showing that "perception and action cycles" are even more instrumental than physical systems in furthering the entropy production: "Living things with the capacity to perceive how and where they are moving, and with the coordinate capacity to move in ways that allow them to perceive more and to perceive better, expand the patches of the planet in which energy degradation can take place.... they expand the Earth's dissipative space. Thus the purpose of living things are differentiations or productions, literally higher order symmetry states, of the environment itself towards its own ends" (Swenson and Turvey 1991). The implication of Swenson work for the foundation of biosemiotic theory are obvious and has been discussed elsewhere (Hoffmeyer 1997 a).

In drawing attention to Swenson's work I want to emphasize that the challenge of intentionality is in no way excluded from the horizon of modern science. A whole range of different approaches to the challenge of intentionality has actually been suggested in recent years. A thorough discussion of much of this work can be found in the American philosopher Alicia Juarrero book on intentional behavior as a complex system (Juarrero 1999).

Unfortunately, as I understand it, the semiotic dimension of intentionality is not sufficiently appreciated in much of this work and is not at all dealt with by so-called

dynamical systems theory (Port and van Gelder 1995). Before approaching the problem of natural translation we shall have to take a brief look at this new approach.

FROM DYNAMICAL SYSTEMS THEORY TO BIOSEMIOTICS

Dynamical systems theory is a mathematical tool for the study of complex material systems which has persuaded many researchers to believe in the reality of so-called *self-organization*. Self-organization is seen as a process by which energetically open systems of many components tend to reach a particular state, a set of circling states or a small volume of their state space (called an attractor basin), with no external interference. This attractor behavior is often recognized at a different level as the spontaneous formation of well organized structures, patterns or behaviors, from random initial conditions, and this gives the impression of emergent behavior or order (Rocha forthcoming). Dynamical systems theory, in other words, has shown us that there is a propensity for matter to self-organize (e.g. (Kauffman 1993)).

In cognitive science dynamical systems theory has come to be seen as an alternative to the prevailing "symbolic" or "computational" school which sees human cognition as based on the manipulation of symbolic objects. Human mind, according to the "symbolic" view, 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. Here it should be noticed that the materiality of this "physical symbol system" was deemed absolutely irrelevant for its workings (Newell and Simon 1975). Dynamical systems theory on the other hand has made it possible to conceive of complex behavior and supposedly of human cognition as arising interactively from the structure of the environment in conjunction with the creature's internal dynamics. Cognition is based on dynamic interaction of material units rather than on logical operations of symbolic units; on situated emergence rather than on hierarchically organized planning systems. "A natural creature's behavior does not need to be preplanned" (Hendriks-Jansen 1996, 325). And, as Robert Port has emphasized, "human cognitive behavior must

unfold in real (that is, continuous, historical) time", contrary to digital computers that are engineered with a constant-rate control clock that synchronizes all computational activity on the chip (Port 1998). In short, dynamical systems theory sees cognition as an embodied process rather than a logical process.

Considering this longstanding controversy it is perhaps understandable that dynamic systems theory has given rise to a widespread rejection of all kinds of "representationalisms" (Goodwin 1995; Maturana and Varela 1987; Van Gelder and Port 1995). It is however possible to reject the computationalism of traditional cognitive science and yet maintain that some kind of representation must necessarily be involved in processes of life and cognition. This is the route taken by biosemiotics (Cariani 1998; Emmeche 1991; Hoffmeyer 1992; Hoffmeyer 1996 b; Hoffmeyer 1997 a; Hoffmeyer 2000; Hoffmeyer forthcoming a; Hoffmeyer and Emmeche 1991; Rocha forthcoming).

Very early on the American physicist Howard Pattee suggested that "We need simpler embodiments of *natural* matter-symbol systems with both empirical power and conceptual generality" (Pattee 1982). Pattee's thinking was inspired by John von Neumann who observed that replication in real existing cells (as opposed to cellular automata) requires not only dynamical fabrication, i.e. e. active enzymatic rate control of synthesis, but also non-dynamical ("quiescent") constraints, i.e. e. genetic memory description (von Neumann 1966). How such functional organization could arise was to him "a miracle of the first magnitude" says Howard Pattee (Pattee 2000).

Howard Pattee further developed this "complementarity" between "dynamic and linguistic modes of complex systems" (Pattee 1973; Pattee 1997). He sees living systems as inherently engaged in measuring processes, and this creates an epistemological problem: "We must define an *epistemic cut* separating the world from the organism or observer" (Pattee 1997) (*italics mine*). The concept of semantic information requires the separation of the knower and the known. Pattee underlines that he is not suggesting a Cartesian dualism here but only a "descriptive dualism", for although a measuring process depends on choices which cannot be derived from

laws, such choices should be seen as functions coded in DNA and ultimately generated by natural selection.

Ultimately then the symbolic mode is seen by Pattee as rooted in the historical nature of living systems, in evolution. Evolution creates unique individuals with unique adaptive strategies: The reason why dynamic systems theory is not sufficient for understanding the workings of life is that it is blind to individual and local history which is where all true evolution occurs:

"We specifically restrict physical laws to describe only those properties of matter that are, by principles of invariance and symmetry, as independent of observers and individual measurements as possible. This is necessary to achieve the characteristic universality of laws... In other words, only those universal and intrinsic aspects of matter that have *no* significance for individuals are described by laws, while those context-dependent, selective aspects of matter that have significance for individuals in a local environment are described by symbols" (Pattee 1995).

CODE-DUALITY

While I endorse the semiotic implications of these ideas I find it hard to accept the dichotomy of symbolic (time-independent) and dynamic (rate-dependent) modes (Hoffmeyer 2000). This dichotomy tends to reinforce the identification of biological information with the sequential information carried in nucleic acids (DNA and RNA) (see Sarkar (1996) for a criticism of this conception of information) and to blind us to the significance of information which might be present in the form of e.g. cytoplasmic architecture and membrane bound processes etc. And while I can agree with Pattee that genetic information deserves to be considered symbolic, since the "meaning" of any single gene is intricately bound to the total genomic system of "meanings", I think that symbolic signification is only one very restricted kind of biological signification. By focusing exclusively on the referential category of symbols it becomes nearly impossible to understand how referential processes could ever have originated in nature (Hoffmeyer forthcoming a).

This is why I have suggested the term Code-Duality to describe the semiotic dynamics of life (Hoffmeyer 1987; Hoffmeyer and Emmeche 1991). Organismic and cellular function is very much dependent on surface properties, shapes and topological ordering of macromolecules in relation to the subcellular architecture of membranes which extend throughout the cellular body. Subcellular architecture is itself molded by evolutionary processes and thus represents successful responses to cellular, bodily, or environmental challenges of the past which are most often also challenges of the present and very probably of the future.

But these representations are not sequential or digital. Rather they are *analog codes* for particular events and situations. The stereochemistry of a receptor molecule on the surface of a cell may for instance be constrained so that the receptor will recognize and bind only a certain kind of hormone molecule, say adrenaline, and no other. Thus the receptor is an analog code for adrenaline - in this case created very early in evolution and fine-tuned in its fit through hundreds of millions of generations.

While Pattee seems to include such processes in the rate-dependent dynamics of the cell I suggest we recognize them as elements in a semiotic system based on analog codings. We thus get a code-duality between the digital and symbolic code of DNA and the analog and indexical or iconic code of essentially all other bodily structures or activities (from the cellular level to the morphological and behavioral levels). By so doing we reduce the insurmountable problem of explaining the origin of symbolicity from purely dynamic processes to the problem of accounting for the emergence of increasingly more developed categories of signs from icons to symbols. Terrence Deacon has suggested essentially the same strategy for explaining the evolutionary origin of human language (Deacon 1997).

And by introducing code-duality we immediately arrive at the scene of *natural translation*: The perpetual transmission down through generations of ontogenetic messages shuffled back and forth between digital and analog codes. This idea, of course, presupposes semiosis to be part of life from the earliest origins as suggested by Swenson's work and as intuited by Thomas Sebeok's well-known statement 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 1976, p.69). I have suggested that life and semiosis co-evolved through a prebiotic process of membrane closing followed by an "interiorization process" in which the membranes built up an asymmetry between their excluded interiors and exteriors (Hoffmeyer 1998): "Prebiotic membranes 'choose to prefer' their insides from their outsides, or one might perhaps see this as a sort of colonization of the interior space. The membranes scaffolded themselves through the formation of a multitude of autocatalytic metabolic loops and finally of replicative molecules mapping constituents of the internal autocatalytic system. Thus persistent architectures appeared as entities engaged in the trick of conjuring up a virtual reality at their insides for the purpose of coping effectively with the their outsides" (Hoffmeyer 2000).

NATURAL TRANSLATION

Traditionally biology has reserved the term translation for that particular process whereby the nucleotide sequence of a messenger RNA (mRNA) molecule is converted into a sequence of amino acids making up a polypeptide chain or a protein molecule. Contradistinctively the transformation of the nucleotide sequence of DNA to a nucleotide sequence of mRNA is called transcription. The difference between these two processes is that in transcription a sequence of one kind of nucleotides, so-called desoxyribo-nucleotides, is transformed into a sequence of another kind of nucleotides, namely ribo-nucleotides, whereas in protein synthesis sequences of triplets of nucleotides are converted into sequences of a very different kind of monomer, amino acids. Formally this difference corresponds quite well to the difference between converting G-key notes to F-key notes and converting F-key notes to bass figurations.

However, if by natural translation we understand any process whereby a potential message is made accessible to a natural system that would not otherwise be

capable of making sense of this message, then nature certainly has developed many other kinds of translation processes at different scales.

In one end of the scale we find receptor processes in the membranes of single cells translating the exterior concentration of signal molecules to specific biochemical activity inside the cell. This kind of translations may eventually be faked by viruses gaining admittance to the interior space of host cells by presenting an icon, i.e., a specific molecular shape "resembling" the shape of a normal signal molecule, to the receptors at the host cell membrane. In the other end of the scale we find for instance brain processes in migratory birds translating specific configurations of stars to neuro-muscular activity destined to bring the birds from winter locations to summer locations or vice versa. In this case human experimenters are capable of fooling the translation process by placing the birds in a dark space with artificial stars in the ceiling. By manipulating the configurations of the artificial stars birds may be lead to fly in directions chosen by the experimenter.

Ecologists have introduced the term ecological niche for the range of each environmental variable, such as temperature, humidity, and food items, within which a species can exist and reproduce. A further distinction can be made between the preferred niche, i.e. the one in which the species performs best, and the realized niche, i. e. the one in which it actually comes to live in a particular environment. The ecological niche concept is not, however, normally broadened to encompass the semiotic aspects of the lives of organisms. I have suggested the term semiotic niche to describe that subset of the local semiosphere which the species must be capable of controlling, and I further suggested that mastering of the semiotic niche conditions were vital to the success of an organism¹(Hoffmeyer 1996 b). This idea should be integrated into the *Umweltslehre* of the German biologist Jakob von Uexküll, who saw the importance of these aspects of life before anybody else: "One can never hope

¹ The term semiosphere is used here in a more objective sense than originally given to the concept by Juri Lotman (Lotman 1990), i.e. as a global sphere of signs unfolding itself in the biosphere. Semiosis is a temporal process (like life or *bios*) and the spatial term semiosphere is therefore an analytical abstraction (just like the biosphere).

to understand the dynamics of the ecosystem without allowing for some form of Umwelt theory" (*ibid*, p. 59).

The semiotic niche is a more subtle and also a much richer concept than the ecological niche since it encompasses all latently relevant cues that has to be correctly interpreted by the organism if its success shall be assured. Since the number of features of the world which may in some situation or other become relevant cues governing the behavior of an organism is infinite or at least orders of magnitudes bigger than the number of features with which the organism has to interact physically, the semiotic aspect opens the door to a very versatile adaptive landscape. Thus a bird, to take an example, not only have to deal with a range of items for food or shelter but also with patterns of sounds, directions and speeds of wind, differences in temperature of air or wind, changing intensities and wavelengths of light etc. or even, as we saw in the case of some migratory birds, with the shifting constellations of stars. In other words, the bird must learn to translate all such cues to meaningful behavior.

This brings us to a point that should be emphasized. Signs may be very indirectly connected to their referents and learning by association is a very pronounced aspect of all organismic existence. Taken together this creates the basis for what I take to be perhaps the most important mechanism underlying evolution: *Semetic interaction*, the creative interaction of habits (etos) and signs (semeion) (Hoffmeyer 1997 c). For illustration let us consider the case of caterpillars munching upon the leaves of corn seedlings (Hoffman 1992; Krampen 1992). Here the munching process evokes an interpretant to be formed in the damaged leave cells in the form of a (unknown) molecular message that is carried around to all the leaves. Healthy leaves understand the message as an instruction to produce a certain volatile substance (a terpenoid) which is then emitted to the air. Wind will carry the terpenoid away and eventually certain wasps will absorb it where it may then eventually provoke the formation of an interpretant in the form of muscular contractions destined to bring the wasp to the emitter of the volatile substance. When the wasp arrives here it senses the presence of the caterpillar and its body is induced to perform the chain of

movements necessary for injecting its eggs into it. Upon hatching the wasp larvae eventually eat and kill the caterpillar.

Seen from above what happens is that the wasp and the corn seedling has a common, if opposite, interest in the caterpillar and that they have found a productive way to cooperate in this interest by entering a shared dimension of the semiosphere². Most interestingly, wasps are not attracted by the terpenoid the first time they come upon it, they have to learn how to interpret the substance. Or to state this differently, a habit, i.e. the corn seedling's emission of a certain terpenoid when attacked by caterpillars, has become a sign leading the wasp to the caterpillar. But then the wasp's acquired habit of letting itself be attracted by this specific terpenoid is now available as a potential sign "calling out" for new interpretations. If the wasp has any natural enemies these would do a good job in understanding this sign, i.e. in learning to interpret the same terpenoid as referring to the potential presence of wasps. This last reflection is of course purely speculative and perhaps even not very likely, but it brings out the clear logic of this mechanism, whereby evolution proceeds through the perpetual extension of the chain or web of cellular or organismic habits that are in the end simply interpretants (Hoffmeyer forthcoming b).

In brief: Each new habit, whether based on learning or genetic specification, exposes the organisms to new challenges either directly or indirectly through the unending chain of translations. All of this nicely reflects the Peircean idea of nature's tendency to take habits, the amazing ability of living systems to translate all kinds of patterns to their own significative universe, to let them enter their Umwelts³.

² Note here that the possibility for sharing a small fragment of the semiosphere presupposes that the semiosphere is not itself a purely subjective category. Interspecific communication is possible because Umwelts being in essence virtual realities are subjective and yet dependent on an objective world of cues, the semiosphere. In fact this is why science is possible. John Deely has put it this way: "The notion of reality and the notion of the Umwelt are, from the point of view of experience, inseparable. Yet what is distinctive about human experience in contrast to a purely perceptually structured consciousness is, quite precisely, the discoverability that Umwelt and environment (or physical surroundings) are yet not coextensive. From this bare suspicion of the understanding in its difference from sense arises the whole enterprise of science and technology, on the one hand, and morality as distinct from mores, on the other" (Deely 1990) 60-61)

³ Jakob von Uexküll's Umwelt theory only concerns animals. He did not ascribe Umwelts to plants since they have no nervous system. In stead plants have a "wohnhülle", i.e. a living cell-layer - the dwelling-integument - that enables them to make their choice of stimuli. Following Anderson et al. I

EVOLUTION BY NATURAL TRANSLATION

In the early 20th century Danish geneticist W. Johannsen coined the terms "gene", "genotype" and "phenotype". Johannsen did not himself believe in genes as material entities but maintained that genes should be seen purely as tools for calculation, and he compared the belief in material genes to the belief of ignorant peasants at his time that there were hidden horses inside a railway engine. But an increasingly genocentric biology rapidly grasped Johannsen's concepts and gave them the now well established material interpretation which would ultimately be epitomized through the deciphering of the genetic code in the late 60ies. There remains however to this day a considerable variation in the ways different areas of biology understand the gene (Neumann-Held 1997; Sterelny and Griffiths 1999). And whereas Johannsen's genotype concept had as its task to explain the *genesis* of the phenotype, i.e. the ontogeny of the individual organism, this task was never very much a part of the modern genotype concept, which from the very beginning of fruit fly genetics became closely associated to the transmission between generations of heritable units. In fact, for most of this century ontogeny was a kind of no-mans-land separating genotypes from phenotypes.

One outstanding exception to this trend was the Scottish embryologist Conrad Waddington who made a strong effort to reinstitute a proper position for embryological knowledge in evolutionary biology. Waddington's image of *canalization*, i.e. of development as a ball running down through the valleys of an epigenetic landscape whose features are largely determined as a concerted effect of a multitude of genes, remains a fertile resource for thinking about the developmental process in its relation to evolution (figure 1). Genes in this view do not directly cause traits; they rather assist in laying out the main features of the epigenetic landscape and

shall suggest that we broaden out the Umwelt concept to cover the phenomenal worlds of plants, fungi and protists (Anderson, Deely et al. 1984). Even though such organisms do not possess nervous systems they do have receptors to guide their activities and they do possess some limited kind of semiotic freedom (Hoffmeyer 1992). Having not experienced the molecular revolution of biology Uexküll must be excused for not seeing the strong analogy between traditional sense receptors and the molecular receptors which we now know covers the surfaces of all kinds of cells (bacteria included).

therefore in the pattern of canalisations open to the ontogenetic process. By showing in this dynamic intermediate level, the epigenetic landscape, between genotype and phenotype he was able to transcend the behavioristic black-box conception of the organism and introduce his idea of "genetic assimilation" (Waddington 1957).

FIGURE 1

Essentially this idea departs from the fact that natural selection would be expected to tend towards some kind of balance between flexibility and genetic fixation of adaptable traits. The epigenetic landscape might at some points be sufficiently indeterminate as to allow environmental factors to influence the exact route the ball would follow, i.e. the exact canalization. Thus natural selection might be seen as integrating a dynamic interaction pattern between genetic and environmental factors.

As the reader may have observed Waddington is here offering a new version of the so-called Baldwin effect: (1) Individual organisms interact with the environment in such a way as to produce non-hereditary adaptations; (2) Genetic factors producing similar traits occur in the population; (3) These factors increase in frequency under natural selection. Genetic assimilation however introduced a much needed missing link between step (1) and (2) in this scheme and thereby Waddington hoped that it would meet the objections raised by among others the paleontologist C. C. Simpson that the Baldwin effect would only work if supplied by a neoLamarckian causal mechanism in which nobody believed - then or now. For a biosemiotic treatment of the Baldwin effect see (Kull 1999).

Waddington's ideas did not get much credit from his contemporaries, the father generation of the new synthesis in biology. And when the Baldwin effect finally in this decade saw a revival this was not inside biology proper but in complexity research (Belew and Mitchell 1996).

It may be illuminating to consider the subtleties of the ontogenetic process in some more concrete details. In his fascinating book "The Evolution of Individuality" American biologist Leo Buss offers interesting reflections on the origin of multicellular life (Buss 1987). Buss considers a scenario of competition among cell lines where some cell lines, which would later become the germ cells succeeded in inducing other cell lines to differentiate so as to carry out somatic duties. Here one should keep in mind that the metazoans inherited from their protistan (uni-cellular) ancestors a complete machinery for cell division. The cells of a developing metazoan embryo follows the same rules governing any self-replicating system, i.e. they divide until further replication is limited by some external force. "The metazoan innovation" writes Buss "is the evolution of epigenetic controls on the growth of developing cell lines, which provides restraints on their inherent propensity for self-replication in a precise cascade such that cell lineages organize themselves into a functional bauplan" (*ibid p. 78*).

From the beginning of metazoan life these epigenetic controls were based on semiotic interventions such as for instance the production of 'misinformation' in the form of molecular signals destined to be captured by receptors at the surfaces of neighboring cells and to interfere with these cell's normal adjustment to their environment. Step by step new semiotic controls were built on the top of the previously acquired patterns of semiotic interactions in a historical process, which consisted in the perpetual integration of topological cellular reality into the regulatory machinery of genomic interpretation. Metazoan development today is manifestly a process of the sequential origin of, and interaction between, cell lineages arising in the clonal progression from the zygote. "The fact that metazoans develop via a complex of epigenetic interactions between cell lineages is *prima facie* evidence that the principal modes of metazoan development arose as variants in the course of ontogeny" (*ibid p. 78*).

FIGURE 2

The development of the eyeless mutant of the axolotl may serve as an illustration of the weblike structure woven by history, which is metazoan ontogenesis. Figure 2 depicts the normal sequence of epigenetic events in the development of the amphibian eye. What happens in the *eyeless* mutant of the axolotl is that step b to c in figure 2 is disturbed because the ectoderm of the mutant does not respond to the inducer and the mutant becomes blind. This however, is not the only problem this poor creature has to cope with; it also lacks the capacity for leaving offspring. The reason for this is that the *eyeless* mutant develops a secondary deficiency in the region of the brain called hypothalamus, which will only be properly developed through induction from the eye. In the *eyeless* individual, no eye exists to direct the development of the hypothalamus, the hypothalamus therefore cannot produce the gonadotropin hormones and in their absence the individual becomes sterile. As Buss says: "Ontogeny must re-enact the interactions which gave rise to it" (*ibid p. 97*). Or, in other words, history in the sense of the evolutionary origin of a given pattern of interactive cell-lines, is conserved not only in the form of genetic instructions but also in the coordinated spatio-temporal ordering of the onset of semiotic controls throughout a growing embryonic tissue. As pointed out by Enrico Coen there is no plan for development; or, to be more precise, what plan there is cannot be separated from its execution. Yeats's immortal question, How can we tell the dancer from the dance? is an exact analogy (Coen 1999).

In a dynamical sense this process is analogous to the swarm behavior seen in social insects like termites building a nest, a process which the French biologist P. Pierre Grassé has termed *stigmergie* (Greek = "incite to work") (Grassé 1959). In stigmergic communication the activity of entities (insects - or cells) are continually guided through the evidences of work previously accomplished. Edward O. Wilson suggested the slightly more fitting term *sematectonic communication* for this kind of interactive activity among social insects (Wilson 1975) 186). Sematectonic

communication is one particular case of that more general category of interactions which I have called *semetic interaction* (Hoffmeyer 1997 c).

The important thing in relation to the evolutionary perspective is that the pattern of semetic interactions guiding the embryonic processes are not directly coded in the genetic material but appears as an indirect outcome of reciprocal growth processes among cell-lines. Just like the so-called wave which appears from time to time during the big football games (soccer) is not generated by any directly coded behavioral algorithm but emerges out of the concerted effect of a quite unrelated individual activity. For the wave to appear entities (spectators) must occupy a more or less circular space with a radius which is constrained by the size of human persons and by the sharpness of human vision. The stands must have a certain size and they must to a certain extent be filled up with people, it must not be snowing or storming, temperatures will have to be in the normal summer range etc. etc.

All of these constraints are always more or less automatically fulfilled during normal big football events. Likewise, under normal circumstances the ontogenetic processes obeys a range of constraints which is necessary for the successful accomplishment of the process. The point is that these constraints are not specified by the genetic setup and neither are they self-evident. To a large extent these constraints are assured by the activity of the organisms themselves or their direct ancestors, a process which 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. When geno-centric evolutionists like Richard Dawkins claim that for instance a bird's nest is just a gene's way of producing a new gene it is easily overlooked that genes do not

have such a power unless the bird happens to be born into a habitat in which the proper conditions for nest building are present. The reason why birds are normally born into such habitats is that they inherited not only their genes but also a viable environment from their parents. As Patrick Bateson observed in a review of Dawkin's book *The Selfish Gene*, if we say a nest is a gene's way of making another gene, we may as well say that a gene is a nest's way of making another nest (Bateson 1978). The all too easy metaphor of "self-replicating" genes tends to distract attention from the symmetry between the replication of genes and the replication of many other developmental resources.

This claim for a fundamental symmetry between genes and other developmental resources forms the core of so-called Developmental Systems Theory (DST) inspired by Susan Oyama's seminal book *"The Ontogeny of Information"* (Oyama 1985) and further developed in the work of among others Paul Griffiths and Russell Gray (Griffiths and Gray 1994). "The full range of developmental resources represents a complex system that is replicated in development" writes Griffiths and Gray and continue: "There is much to be said about the different roles of particular resources. But there is nothing that divides the resources into two fundamental kinds. The role of genes is no more unique than the role of many other factors." (Griffiths and Gray 1994, 277).

In DST the emphasis is not on individuals but on "life-cycles", i.e., the series of developmental events, which forms an atomic unit of repetition in a lineage. "Each life-cycle is initiated by a period in which the functional structures characteristic of the lineage must be reconstructed from relatively simple resources. At this point there must be potential variations in the developmental resources to restructure the life cycle in a way that is reflected in descendant cycles" (Griffiths and Gray 1994, 296). As a radical consequence of this view it follows that the traditional separation of organism and environment is called into question. Variant life cycles differ in their capacity to replicate themselves, but the reason why one variant does better than another is not that it corresponds better to some independently existing environmental

feature. Rather the variant is successful because "the life-cycle that includes interaction with that feature has a greater capacity to replicate itself than the life-cycle that lacks that interaction" (*ibid* 300). Life cycles therefore have fitness values but these are no longer a matter of "fittedness" to an independent environment.

DST then is not opposed to the idea of natural selection as a fundamental evolutionary resource but is opposed to the gene-selectionist interpretation of that idea, and Griffiths and Gray quote the Harvard geneticist Richard Lewontin saying that "if anything in the world can be said to be self-replicating, it is not the gene, but the entire organism as a complex system" (Lewontin 1993, p.48).

DST, by rejecting the monistic view of genes as dictatorial determinants of fitness and by allowing the organism-environment interaction an autonomous evolutionary role via the life-cycle concept, necessarily turns our attention to the actual embodied life of organisms in their manifold social and ecological environments. Here the semiotic perspective offers a rich new theoretical tool since it focuses not on the physical interactions of organisms as such but on the semiotic controls regulating these interactions. Evolution, it would seem, cannot be abstracted away from the eco-semiotic context in which it is irreducibly suspended. The semiotic interactions between organisms, the perpetual translations of all kinds of natural regularities, biotic or abiotic, social or individual, intelligent or non-intelligent, genetic or ecological, developmental or adult etc. into meaningful organismic or populational behavior. Returning to Waddington's metaphor of the epigenetic landscape we can see that "the semiotic turn in biology" implies "that in addition to the epigenetic landscape guiding the pattern of developmental canalizations there must also be an epi-developmental, semiotic *Umwelt landscape* canalizing the learning processes whereby a particular Umwelt is calibrated to the actual environmental circumstances"(Hoffmeyer forthcoming b).

We can then extend the DST conception of fitness with the idea of *genetic fitness*: "Genes may be fit only under certain environmental conditions, or environments might perhaps be said to be fit in the sense that their self-sustaining

dynamic capacity has been adapted to the actual genotype resources offered to them. But if genotypes and envirotypes (Odling-Smee and Patten 1994) reciprocally constitute the context on which fitness should be measured, it seems we should rather talk about the fit in its relational entirety, that is as a semiotic capacity. The evolutionarily relevant fitness concept, *semiotic fitness, should ideally measure the semiotic competence or success of natural systems in managing the genotype-envirotypes translation processes*" (Hoffmeyer 1997 b).

And this, I would submit, deserves to be known as the origin of species by means of natural translation. Obviously, if the semiotic fitness of a natural system, in the sense of a semiotically integrated dynamic unit, is low, other such semiotically integrated units will tend to capture a share of their flows of matter and energy, and ultimately such units would tend to disappear. I hesitate to call this process natural selection, because no selection in the true sense of this word is actually involved. Nobody or nothing, and certainly not Nature, selects the high-fitness units on behalf of the low-fitness units. Natural systems are engaged in translations or interpretations, not in selections.

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FIGURE CAPTIONS:

Figure 1: The epigenetic landscape in C. Waddington's original drawing (Waddington 1957).

Figure 2: Development of the amphibian lens, in which the optic vesicle originates as an outpocketing of the cephalic neural tube (a), and in coming into contact with the ectoderm (b) induces the lens placode (c). The lens placode then invaginates to form the optic cup (d) and, eventually, the lens vesicle, as the optic stalk grows into contact with the developing eye (e).