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Classificazione Decimale Dewey:

570.1 (23.) SCIENZE DELLA VITA BIOLOGIA. FILOSOFIA E TEORIA

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THE SEMIOTICS OF COSMIC EVOLUTION

A HIERARCHY OF SPACE-TIME INTERPRETANTS OF QUANTUM INFORMATION

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ISBN
979-12-218-2387-5

PRIMA EDIZIONE
ROMA 6 FEBBRAIO 2026

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INTRODUCTION
THE RISE OF A NEW SCIENTIFIC PARADIGM

Between the beginning of the 20th and the beginning of the 21st century, a new scientific paradigm has developed. Overcoming the classical Newtonian conception of an objective predetermined reality, independent of any *semiotic agency*, this new paradigm suggests that a sequence of space-time *interpretants* of quantum information flowing through inside / outside interfaces gives the hierarchy of cosmic evolution of i) entities endowed with mass-energy, ii) living beings and iii) beings endowed with consciousness. The following basic conceptions mark the temporal stages of development (in order of time) of this new ontology:

1. The collapse of *quantum superposition of states* by interaction between observer and observed in measuring processes.
2. The *relativistic equivalence* between accelerating reference frames and gravitational fields, and the space-time evolution of the universe.
3. The discovery that quantum mechanics and the general theory of relativity are *incompatible*.
4. The introduction of the concept of *interpretant* in Peirce's semiotics.
5. The space-time self-organization and evolution of living organisms that interpret the information of a *genetic code*.
6. The extension of the genetic code into the *linguistic code* of human species.

7. The general theory of *biosemiotic agents* that interpret the information they exchange with their specific environment.
8. The abstraction from quantum mechanics of the general theory of *quantum information*.
9. The discovery of *quantum cognition* and decision making under uncertainty.
10. The general theory of open *quantum biosystems* in biology and social sciences.
11. The hypothesis of the *gravitational collapse* of the quantum superposition of states.
12. The hypothesis that a *quantum cosmic code* rules the relativistic space-time evolution of the universe.

The confluence of these new conceptions at the beginning of the 21st century led several authors to understand that quantum information is the *cosmic code* that connects the space-time evolution of matter, living beings and beings endowed with self-awareness. This confluence of new ideas also led some authors to think, even if not yet in a clear and explicit way, that the incompatibility between the general relativity and quantum theory may be solved if the macroscopic space-time forms of the universe are conceived as the *interpretants* of microscopic quantum information. This short essay aims to make it clear and explicit the transfer of information from microscopic quantum entities to macroscopic space-time forms, highlighting the hierarchy of the space-time interpretants that display the *meaning* of quantum information. In this way the new, surprising conception of *the semiotics of cosmic evolution* will be outlined.

This essay is an extension from biosemiotics to cosmic semiotics of my previous essay in Italian entitled *L'evoluzione delle specie semiotiche. Biologia dell'evoluzione, semiotica e informazione quantistica* (Aracne 2024). In this new revised English edition, I try to give, as much as possible, a more concise, clear and systematic exposition of such a complex subject. I am grateful to my friend psychiatrist Alessandro Pesavento and to my wife Evelina, who helped me to improve the clarity of the presentation of the topic.

CHAPTER I

THE SEMIOTICS OF LIVING BEINGS (BIOSEMIOTICS)

In a 1867 paper entitled *On a New List of Categories* and in a later 1902 essay that marks the transition from categories to semiotics (see *Collected Papers* vol. I and II), the chemist, physicist, mathematician and philosopher Charles Sanders Peirce – famous for his studies on the logic of relations and founder of American pragmatism – sets out the three categories of *firstness*, *secondness* and *thirdness* which are the foundation of semiotics, the science of the relationship among sign, object and interpretant in communication processes. The monadic category of firstness refers to the potentiality of *sign*, the dyadic category of secondness refers to the actualization of the potentiality of sign in its relationship with *object*, the ternary category of thirdness refers to the meaning of relationship between sign and object in its relationship with *interpretant*. Peirce also matched the three categories of firstness, secondness and thirdness to the fundamental division of signs into *icon*, *index* and *symbol*, respectively. All this will have to be reconsidered.

In his seminal 1926 work, *Theoretical Biology*, biologist Jakob von Uexküll states that "it is possible to outline a common scheme on the basis of which all the constructive plans of animals and the environments that depend on them are constructed". Each living organism (starting from the cell) is characterized, on the one hand, by the separation between an *internal* and an *external* environment, on the other, by communication between the two environments by means of receptor

and effector organs. The objects of the external world (*umwelt*) that are essential for the survival of the individual and the species are the bearers of perceptual and effectual characteristics that are significant for the subject, while the transmission of the effects of these characteristics from the receptor to the effector organs constitutes the inner world (*innenwelt*) of the subject. Uexküll believes that living organisms cannot be considered as 'physico-chemical machines' and that the 'conformity to a plan' of their organization requires the development of a new science, *theoretical biology*.

Towards the end of the 20th century, the biochemist Jesper Hoffmeyer proposes a synthesis between Peirce's semiotics, von Uexküll's theoretical biology and evolutionary biology, introducing the new conception of biosemiotic*s*. According to this theory, living beings are *semiotic agents that evolve by interpreting the information they exchange with their umwelt*. Hoffmeyer believes that two principles underlie the organization of living beings: a hierarchy of inside / outside interfaces and what he calls the duality of code, that is the interchange between an *analog* space-time metabolism and the information given by a *digital* genetic code. At the same time, biochemist Eugenio Andrade proposes an analysis of biosemiotic *self-organization* of living organisms considered as open nonlinear systems far from thermodynamic equilibrium.

1.1. The self-organization of nonlinear open systems by spontaneous symmmetry breaking

In a noteworthy essay titled *Los demonios de Darwin. Semiótica y Termodinámica de la Evolución Biológica* (2003), biochemist Eugenio Andrade describes the connection between semiotics, statistical mechanics and evolutionary biology in a particularly clear and systematic way. According to Andrade living organisms are semiotic agents that would behave like Maxwell's demon. In an imaginary experiment, Maxwell considered a container containing a gas at uniform temperature, divided into two compartments A and B by a wall containing a small trapdoor. A little devil guarding the trapdoor that allowed the slower molecules to pass through A and the faster ones through B

would decrease the entropy of A and increase that of B. Such a *symmetry breaking* can occur spontaneously in a non linear and open dynamical system (consisting of a myriad of interacting parts) due to the bifurcation of an unstable critical state of the system into two (or more) stable states far from thermodynamic equilibrium (cf. Nicolis and Prigogine).

Living organisms are open systems that exchange matter and energy with their specific environment. This flow of mass-energy generates an imbalance giving rise to an amplification of spontaneous internal fluctuations, and to a reaction in the opposite direction that tends to re-establish the anterior configuration. But, once a threshold of stability has been exceeded, these fluctuations can destroy the initial structure and generate unpredictable structural changes:

> As external forces become more intense, the deviation from equilibrium increases and linearity in the system's behavior is lost… This is the process of self-organization that gives rise to 'dissipative structures', so called because they generate order at the cost of dissipating entropy in the environment… In this respect, the behavior of systems far from equilibrium exhibits characteristics comparable to those described by the process of evolution, such as rapid speciation followed by periods of stasis… Further away from equilibrium, further alternatives or choices are produced. Like a branching tree, there are bifurcation nodes where behavior is unpredictable; however, once the branch along which the system develops is defined, the behavior of the system becomes predictable. The record of successive bifurcations corresponds to the history of the system… (Andrade 2003, p. 31-32, 33, 35-36, my translation from Spanish).

A living being self-organizes with the introjection of information or negative entropy $\Delta S_i < 0$ inside itself and the projection of entropy $\Delta S_e > 0$ into the external environment (in a global process in which $\Delta S_e + \Delta S_i > 0$). This is made possible by the fact that a living organism, as a semiotic agent, carries out an environmental selection process organized in a hierarchical structure, whereby some of the *possible* connections between the parts at a lower level (Peirce's *firstness*) are put in place at a given level (Peirce's *secondness*) under the control of a higher level (Peirce's *thirdness*). This semiotics will be reconsidered later.

> Selection presupposes an agent with the ability to distinguish the different alternatives that are presented to it. In the web of interactions, systems 'recognize' some elements of their environment, whose set constitutes their world of experience. These representations of the external world are generated as a result of signals captured by means of sensors or structural modules that show some kind of affinity for some elements of the environment; that is, the capacity for classification is inherent to the structure. By means of selection, organisms eliminate the confusion given by the multiplicity of entities, creating their own world of interactions, and in this way they shape the surrounding world… Furthermore, selection alone is insufficient, since the selecting agent must be able to memorize or fix the information obtained. The selection materializes in the recording. The recording of information… becomes the embodied knowledge necessary for living and performing adequately in a given environment. (Andrade 2003, p. 121, 123, my translation).

Both Andade and Hoffmeyer, respectively in their 2003 and 2008 biosemiotics essays, cite geneticist Waddington's idea of *developmental canalization* for under-standing the ontogenetic self-organization of living beings:

> According to Waddington, the ontogenetic process may be seen as analogous to a ball running downhill through a branching system of valleys in an *epigenetic landscape*, the contours of which are determined as the effect of interplay between multiple individual genes (Hoffmeyer 2008, p.198).

1.2. A hierarchy of inside / outside interfaces

Andrade highlights, in biological evolution, a hierarchical structure in which there are units contained in units at a higher level and units that contain others at a lower level. The units of each level are relatively independent, with their own rules of structuring and their own rhythms, faster in the lower levels, slower in the higher ones; such units also have a dual nature, *ecological* (analogical) and *genealogical* (digital),

and a simultaneously random and deterministic behavior associated, respectively, with the variations of the lower levels (susceptible to amplification far from equilibrium) and with the restrictions exerted by the higher levels. Finally, the dynamics of the semiotic agents of each level of this hierarchical structure presupposes at least three levels of organization:

> Each level must be studied as such and in reference to the two adjacent levels, lower and higher. The study of the unity and activity proper to each level inevitably refers to its lower and higher referents, just as Peirce's *Secondity* is explained in function of a *Firstness* and a *Thirdness*. The *Secondity* or level of study reflects an activity starting from a chance or potentiality contained in the immediately lower level, *Firstness*, and from an organizing activity that acts within the restrictions imposed by the higher level, *Thirdness*. The unity inevitably reflects the triad. Eldredge proposes the existence of ecological and genealogical hierarchies… There is no doubt that there is a strong reciprocal interaction between ecological and genealogical processes. The introduction of a new variation in genealogical entities at each level, as well as its selection, are influenced by their interaction with the environment. (Andrade 2003, p. 219, 221, my translation).

In the Chapter *Surfaces within Surface*, of his seminal essay titled *Biosemiotics: signs of life and life of signs* (2008), biochemist Jesper Hoffmeyer points out that:

> From the biosemiotics viewpoint… the generation of autocatalytic self-sufficiency is only a necessary *first step* on the way from a chemical system to a living system…Beyond this, we must add a *second step*, which is the establishment of the very conditions that could make semiosis possible in the first place – i.e., the generation of a closed membrane around such an autocatalytically closed system of chemical components and thereby *the creation of a basic asymmetry between an inside and an outside, making the membrane a potential interface structure through which the autocatalytic mix on the inside might learn to adjust cleverly to conditions outside* (Hoffmeyer 2008, p. 34).

Hoffmeyer also outlines the hierarchical structure of living beings, from the whole organism down to cells and also inside the cell, 'whose biological membrane is composed of a simple lipid bilayer mixed with numerous protein molecules':

> For when we next move *into* the cell, we again encounter a plethora of biologically important surfaces. The cell's interior is packed with bodies inside bodies, e.g., the organelles with names such as mitochondria, lysosomes, Golgi apparati, cell nuclei, and the endoplasmic reticulum… And across all of these membranes there occurs constant biosemiotic activity whereby molecular messages are exchanged in order to bring the biochemical functions on the inside and the outside of these interior membranes into concordance (Hoffmeyer 2008, p. 27).

This hierarchical structure of living beings expresses the result of their evolution, from primordial prokaryotic to eukaryotic cells, which incorporate prokaryotic cells as their mitochondria, up to the differentiation of cells into the tissues and organs of multi-cellular organisms.

1.3. The analog-digital duality of code in the evolution of living beings

In addition to self-organization and to the hierarchy of inside / outside interfaces, another principle underlies the organization of living beings: the analog / digital duality of code. This principle highlights the complementarity between: i) the *digital* coding of information by the linear sequences of nucleotides of DNA and RNA and ii) the *analog* coding of information by the stereochemical enzyme-substrate complexes of proteins. Andrade criticizes the Darwinian conception of adaptation by environmental selection alone and the central dogma of the DNA → RNA → protein sequence, and considers it essential that, since semiotic agents are simultaneously subject and object of selection, in the alternation between phenotype and genotype there is a continuous transformation of information from analog to digital and vice versa:

> The transition from the analog form (phenotype) to the digital form (genotype) is a process that takes place at the population level through sexual reproduction, which generates new genetic combinations characteristic of new organisms. While the transition from the digital form (genotype) to the analog one (phenotype) is represented by the process of ontogenesis or development that allows the individuation or space-time realization of individuals… The cellular structure actively participates in its own development. However, the analog information contained in the cellular structure is not part of the digital description in the DNA. In other words, the information in the DNA does nothing on its own unless an active operator reads and interprets it. Digital recordings do not directly intervene in the energetic transactions inherent in biological interactions (Andrade 2003, p. 165, my translation).

According to Andrade, the 'compression' of coding from analog (three-dimensional) to digital (linear) is equivalent to the transition from a concrete space-time image to an abstract statement: it involves the loss of the information relating to the context. Under equilibrium conditions, the slow variation of organisms through random mutation depends more on their genealogical history than on the surrounding environment; but extreme and sudden changes in environmental conditions, far from equilibrium, accelerate genetic mutation and direct it towards the production of new and rapid adaptive interactions between organism and environment.

In addition to criticizing Darwin's conception of evolution and the central dogma of molecular biology, Andrade criticizes Shannon's information theory. In Shannon's view, an external observer is concerned with measuring the amount of information and the uncertainty of the message, but not with its meaning. In Andrade's conception of living beings as semiotic agents, a living being can be considered as an *interpretant* (Peirce's thirdness) that realizes the *potentiality of information* (Peirce's firstness) as its *actual meaning* (Peirce's secondness), in a cyclical, non-linear process of reciprocal feedback between the two types of information (this semiotics will be modified in Chap. 2.1):

> The same signal can be interpreted differently depending on its receiver. Information requires the receiver to be able to distinguish signal

> from noise, decipher the message features, and establish a relationship between them. The receiver defines the context. Interpreting the message means clarifying the meaning it conveys, that is, the fulfillment of a function. Maxwell's demons are not conceived as mere passive receptors of information… The transition from potentiality to actuality is due to measurement; similarly, the transition from firstness to secondness requires thirdness. We humans are not the only ones who measure and process records; all living beings do so… The accumulation of information has had to pay a very high price; many organisms have perished in the selection process that gave rise to each particular genome. The organism saves the trials and errors that its ancestors have done (Andrade 2003, p. 181-182, 188, my translation).

In the *Epilogue* of his 2003 essay Andrade points out that the conception of living beings as semiotic agents, overcoming the limitations of Darwin's agentless selection and of the meaning-free information of the central dogma of molecular biology, seeks to definitively abandon the mechanistic conception of nature as a machine, dominant in the previous centuries.

Andrade's conception of life as semiotic agency is in agreement with that of Hoffmeyer. In his 2008 essay *Biosemiotics*, Hoffmeyer points out that "the shift of emphasis from DNA to the membrane interface solves a problem that has long been a mystery to biology – i.e., that of how a one-dimensional and fairly static molecule such as DNA could be able to specify the generation of a three-dimensional embryo in time and space":

> There is, in fact, no reason to expect that the lifeless DNA molecule would be capable of such a counterintuitive feat. Yet where there is DNA, there is allways also the cell with its membranes, whose patterned organization is autonomously determined by the continuity of cellular life through cell division. Living cells, through their membranes, use DNA to construct the organism, not vice versa. It is the active functioning of these membranes as well as the membrane-connected proteins that direct life's activity, not the passive and inanimate DNA. It is, in other words, in the semiotic functioning of the cellular membranes that we shall seek what can be called life's *agency*, its inherent future-directedness, its survival project. It follows from these considerations that the generation of membranes has been the principal

milestone along the path that led to the emergence of life on our planet some four billions years ago (Hoffmeyer 2008, p. 31-32).

Living beings are located in three-dimensional space and their introjection of negative entropy lasts only a certain amount of time. The genetic code provides an *abstract description* of an organism that allows it to reproduce in a new organism a copy of itself at the level of complexity it has achieved, without having to start from the beginning with a new series of trials and errors; if such abstract description could be expressed through an analog code, only very simple organisms would be possible. The interpretation of the message of digital code then determines what kind of differences in its environments (both internal and external) the new organism will actually select during its development, so addressing its realization in space and time. Before this advantage of abstract description – especially that of the regulatory genes that function as meta-messages providing creative plasticity to the evolutionary process –, Hoffmeyer states two other advantages of digital codes:

> The first [advantage] is that *messages expressed in digital codes do not have to observe the limitations of freedom imposed by natural laws*. Possible as well as impossile messages may be expressed in digital codes… And in fact, this happens all the time (among other reasons, because of the genetic crossing-over processes, whereby the hereditary material is recombined in new – and not always viable – patterns). It is this property of digital codes that explains the surprising evolutionary *creativity* of living systems, the incredible combinatorial capacity and the consequent incessant testing of the eventual limits for possible combinations. The second advantage of digital codes is their *time indepedence* and consensual *objectivity*. Digital codes are ideal codes for memory… Thanks to its secluded existence in protected isolation from the metabolic jungle of the cell – and thus due to its very passivity – the DNA code is capable of conserving experiences (in the sense of nucleotide sequences) shaped by past survival outcomes under the then prevailing ecological conditions. Such structures are inherently signs of these past relations, and this is exactly why genes are not functional in themselves, but must be unfolded through the operation of an interpreting agency (Hoffmeyer 2008, p. 86-87).

CHAPTER II

THE SEMIOTICS OF BEINGS ENDOWED WITH SELF-AWARENESS

Between the end of the 20th century and the beginning of the 21st century, what was called the second quantum revolution developed after the one at the beginning of the 20th century: this consisted in the abstraction from quantum mechanics of the general theory of *quantum information*, applied especially to quantum computers (see Rau 2021), and the discovery of the relation between quantum entities and concepts which resulted in the theory of *quantum cognition*, applied to symbolic language. Pointing out that the micro-physical entities of quantum mechanics are non-spatial (non-local), the Belgian physicist Diederik Aerts proposed in 2009 a conceptuality interpretation of quantum theory, which, as we will see in chapter 3, will have important implications for the conception of a cosmic code:

> So, to make sense of quantum mechanics, the first thing one needs to do is to find a notion specifying what the nature of a micro-physical entity is. We know it is not a particle notion, or a wave notion, nor a waveparticle notion, so, what is it?... As Arthur Conan Doyle used to point out more than once, in his Sherlock Holmes stories, sometimes the best place to hide something is to keep it in plain sight. And according to the conceptuality interpretation, what has always been in plain sight, but precisely for that was very hard to notice, is that the notion one should use to represent the nature of a quantum entity, and make full sense of its behavior, is the very notion of concept! In other words,