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Cognition and semiotic processing of luminous stimuli in various orders of the natural world

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Abstract: Semiosis, and particularly visual semiosis, is not something unique to humans. All animal species, all living beings (including other forms of life outside the animal kingdom) have semiotic activity. But we can go even beyond that. It is possible to maintain that also in the world that is usually called "inanimate" or "inert" some kind of semiotic activity takes place. This paper proposes a view in which the elements and organisms in the natural environment, instead of being classified into separate categories are thought of as forming a continuous gradation from one to another, from lower to upper levels of complexity and semiotic behavior. From this, and from further arguments, it is possible to maintain that semiosis permeates the entire universe. A special point is made concerning the interaction of light stimuli with matter and living organisms, which in some cases has produced the systems of vision that many animals posses, and in some other cases produce reactions and changes that can be considered as a kind of protosemiotic activity.

Keywords: semiosis, cognition, natural world, light stimuli.

In the *Selected writings*, Peirce says: "It is perfectly true that we can never attain a knowledge of things as they are. We can only know their human aspect. But that is all the universe is for us" (Peirce 1863–1911 [1966: 426]). This, which Peirce applies to humans, is also applicable to other orders of the living world, for instance to other species. The same phrase could be rewritten in this way: It is perfectly true that bees can never attain a knowledge of things as they are. Bees can only know the aspect that is pertinent for them. But that is all the universe is for them.

This can be exemplified with Jakob von Uexküll's drawing (Figure 1). It is from his concept and theory of *Umwelt* that the study of biosemiotics started to be developed. *Umwelt* can be understood as the perceptual world in which an organism lives and acts (Uexküll 1934 [1992]). This world, built by the

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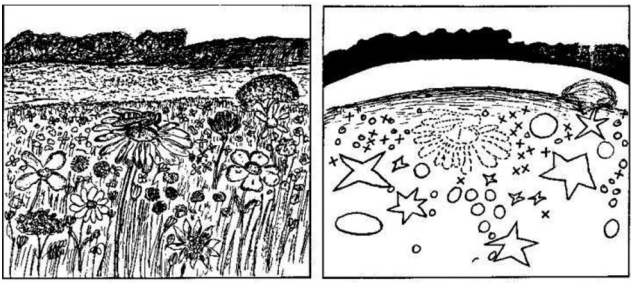

Figure 1: A honey bee in its environment (left) and a representation of its Umwelt, as configured and categorized through its senses (right). From Uexküll (1934 [1992]).

senses, is different for each organism. Figure 1 represents a honey bee in its environment (a field with flowers, a river, the distant silhouette of a forest or mountains). For the senses of the bee, that field has different qualities, another configuration, other categories of elements, which constitute its *Umwelt*. Every organism is equipped to perceive the objects that are meaningful to it. And this is the reality that exists to it, a perceptual world that cannot be shared with other species.

Semiosis, and particularly visual semiosis, is not something unique to humans. All animal species, all living beings (including other forms of life outside the animal kingdom) have semiotic activity. But we can go even beyond that. It is possible to maintain that also in the world that is usually called "inanimate" or "inert" some kind of semiotic activity has place. It is clear that only humans study and analyze semiotics and the different kinds of semiosis, but the semiotic activity is exercised in all orders of the universe.

John Deely (1990: 28–32) includes the semiotic activity of humans (anthroposemiosis), animals (zoosemiosis) and plants (phytosemiosis) within *biosemiosis*, and considers semiotic activity outside it, as well, in what he calls *physiosemiosis*, the interaction of objects in the physical environment, including, for instance, the macroscopic universe: star systems and the development of planetary systems (Figure 2).

Figure 2: John Deely's classification of the types of semiosis (adapted from Deely 1990: 32).

However, Deely makes it clear that cognitive semiosis appears only in the levels of zoosemiosis and anthroposemiosis, while phyto and physiosemiosis constitute lower levels, where we cannot truly speak of cognitive activity.

It has been said that *semiosis* is practically synonymous with *life*. Now, let's begin by discussing the traditional divisions established in the world of living beings, in biology. Are there definite categories in the biological kingdom? Is it possible to clearly separate the category of "animals" from the one of "plants"? What happens with the category of "minerals"?

Some time ago, the natural world was categorized in three kingdoms: animals, plants, and minerals, associated in two big groups: living or animate beings (animals and plants), and inert or inanimate objects (minerals). This classification goes back to Aristotle and is also developed by Linnaeus in 1735. More recently, the categories of fungi, monera, and protista were added to the world of living beings. However, the two big groups – biotic, with life, and abiotic, without life – remain. Table 1 shows how the classificatory idea of living beings was evolving, from 1735, with Linnaeus, until the end of the twentieth century. These classifications exclude the abiotic world.

Without doubt, this table will continue being modified. Will there come a point where there are so many divisions that areas of differentiation between kingdoms or categories become blurred?

Let's have a look at the scheme of Figure 3, a symbiogenetic tree of the six kingdoms. In this diagram some kingdoms are presented as a product of a union or fusion between two previous kingdoms. This is rather different from the image of a traditional tree, where two branches arise from a single branch, and from each of them, other two, and so on (Figure 4). In Figure 3, instead, two branches join together and give origin to a third one, which in turn is joined with some of the previous and give origin to a fourth, etc.

From the observation that the categories in which the biological and the natural world are divided has been constantly changing, and often result in blurred divisions between one category and another, we can advance a hypothesis according to which the world is interpreted by means of continuous gradations or transformations, instead of being explained by tight divisions. Thus, the evolution of a species is envisaged in a continuous way, where different things do indeed appear, but where the differences are accumulated out of slow gradations, not in jumps or breaks. Is it possible to draw a gradation scale of characteristics going from plants to animals? And between living beings and inert objects? Are there organisms or things difficult to classify in one category or another that could be placed "midway" between them?

Table 1: The evolution and change of the classification of natural entities, excluding the abiotic world (adapted from Wikipedia 2015a).

Linnaeus	**Haeckel**	**Chatton**	**Copeland**	**Whittaker**	**Woese et al.**	**Woese et al.**	**Cavalier-Smith**
18th century	19th century	1920s	1930s	1960s	1970s	1990s	1990s
2 kingdoms	***3 kingdoms***	***2 empires***	***4 kingdoms***	***5 kingdoms***	***6 kingdoms***	***3 domains***	***8 kingdoms***
		Prokaryota	**Monera**	**Monera**	**Eubacteria**	**Bacteria**	**Eubacteria**
(not treated)	**Protista**				**Archaebacteria**	**Archaea**	**Archaebacteria**
			Protista	**Protista**	**Protista**		**Archezoa**
		Eukaryota					**Protozoa**
							Chromista
Vegetabilia	**Plantae**		**Plantae**	**Plantae**	**Plantae**	**Eucarya**	**Plantae**
				Fungi	**Fungi**		**Fungi**
Animalia	**Animalia**		**Animalia**	**Animalia**	**Animalia**		**Animalia**

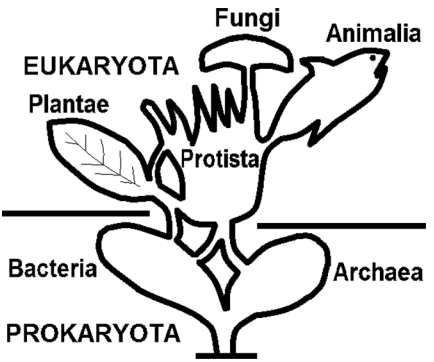

Figure 3: Symbiogenetic tree of the six kingdoms. At present, the symbiogenetic origin of eukaryota by a fusion between an archaea and a bacteria (eukaryogenesis) is considered demonstrated. Later on, the symbiogenesis between a protist and a cyanobacteria originated plantae (adapted from the diagram by Mauricio Lucioni Maristany, published in Wikipedia 2015b).

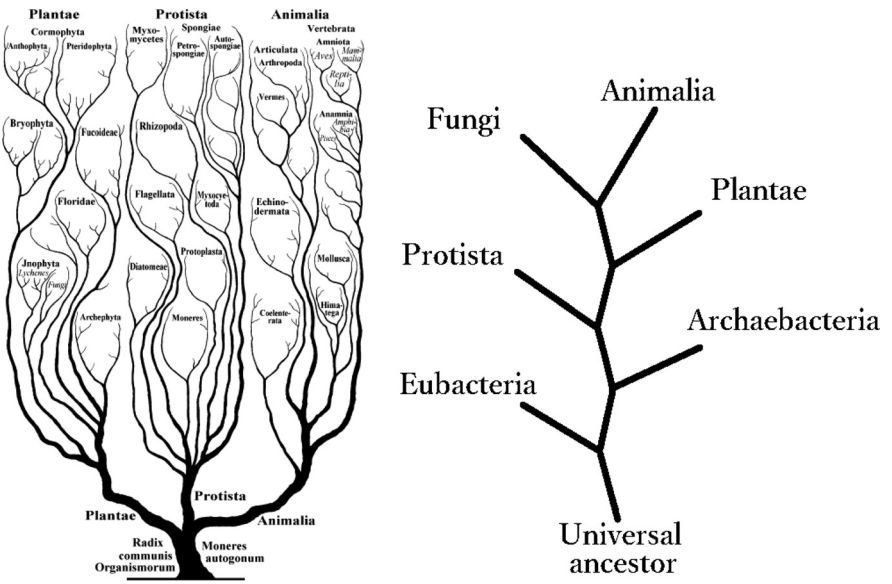

Figure 4: Representation in form of a traditional tree. Left: Tree of life (adapted from Ernst Haeckel, *Generelle Morphologie der Organismen*, Berlin, 1866). Right: Tree of the six kingdoms with their phylogenetic approximate relations (adapted from Wikipedia 2015b).

If the divisions of the biotic world are better explained through gradations, will the same happen for the division between inert things and animate beings? We should remember that the etymology of the word "animate" involves motion (and not necessarily or exclusively motion of living beings). As a matter of fact,

in Greek, *anemos* (wind) has the same root. In this sense, is a planet orbiting a star an inert or inanimate object? Is a star (or our Sun) an inert object too? What is it that moves these objects but certain internal or external forces? If those forces (for instance, gravity) are internal to the planet, could it still be termed an inanimate object? If it is so, in the case of our Earth, how to explain tectonic movements, volcanic activity, tides, wind, etc.?

It is necessary to demonstrate that "inert" materials can interact and interchange physicochemical processes and certain kind of "information" among themselves, while avoiding falling into the human interpretation of these phenomena. For instance, what is the purpose of fluorescence in minerals that have this property? Which changes produce visible radiation in minerals?

Aleksandr Oparin explained the origin of life in terms of physical and chemical processes: a progression from the simplest to the most complex. By this, he broke the vicious circle that asserted that the substances present in living beings can only be fabricated by living beings (Oparin 1938). Stanley Miller's notion of pre-biotic chemistry can be also offered as an explanation of the conditions and reactions that gave origin to life. The central idea of those lines of research is that the emergence of life on Earth was preceded by a gradual sequence of chemical events (Miller and Urey 1959). And, since they originated life (and thus semiosis), we can consider that these events already constitute semiotic processes.

In 1956, in is book *Life, Creating Rocks*, Georges Deflandre explains how sedimentary rocks were built by billions of microscopic organisms (animals, plants, protists) glued together. That is to say, what we usually consider to be a mineral originated from former living organisms, and the transformation that allowed this process still continues. Even "inert" materials can interact among them and produce physicochemical exchanges. Can we invert the title of Deflandre's book, to read instead *Rocks, Creating Life*?

Is it possible to say that rocks have semiotic activity? If we understand semiosis as any form of activity or process involving signs (i.e., something that stands for some other thing and creates a third), there would be not too much objections, certainly. One of the simplest, more abstract and comprehensive definitions by Peirce reads: "By 'semiosis' I mean [...] an action, or influence, which is, or involves, a cooperation of *three* subjects, such as a sign, its object, and its interpretant" (Peirce 1860–1908: 5.484). In an example given by Deely, concurring with Deflandre's thesis, the sign is a dinosaur bone, the object is the extinct dinosaur of which the bone gives proof, and the interpretant is the geological stone formation into which the bone was transformed after millions of years. In this case, the interpretant is a physical

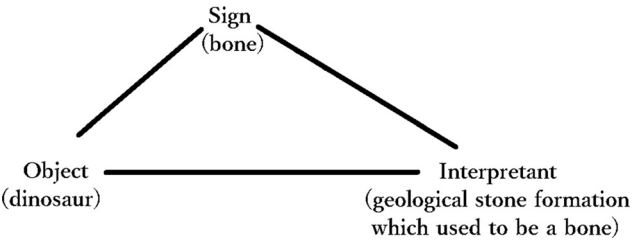

Figure 5: Peircean semiotic triangle with an example from the natural environment (adapted from Deely 1990: 90).

entity (Figure 5). Deely calls this virtual semiosis, something prior to cognitive life (Deely 1990: 90–91).

Let's turn to cases in which semiosis is produced in relation to luminous radiation, something that finally will give origin to the vision systems in animals. In all orders of nature, both living beings and the rest of matter perform some kind of interaction with luminous radiation. In the case of animals, this is accomplished through some kind of vision system; in the case of plants, through the mechanism of phototropism. Some specialized receptors, called phototropins make the plant grow in the direction of light, produce photosynthesis and react to any change of intensity and even color of light. Normally, this mechanism is not termed "a vision system," but truly speaking it is not far from being it.

In the case of minerals, there are also reactions to luminous radiation. There are the special cases of luminescence and fluorescence, as well as the normal processes of absorption, transmission, reflection, scattering, and refraction of light, that are common to any kind of matter, either organic or inorganic (Figure 6).

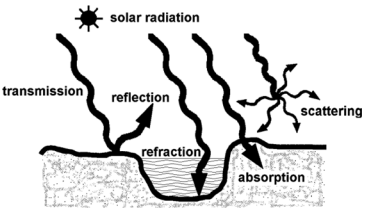

Figure 6: Interactions of light with matter (redrawn from Oklahoma Climatological Survey 1997, http://okfirst.mesonet.org/train/meteorology/Radiation.html).

Luminescence is a characteristic of some substances that emit light (visible radiation) when they are excited by certain radiations (ultraviolet or other non-visible radiations) or by mechanical or thermal energy. *Fluorescence* is a particular kind of luminescence. *Phosphorescence* is another kind of luminescence that remains for a certain time after the radiation ceases. *Triboluminescence* is an emission of light

produced by some materials subjected to mechanical stress. Quartz is triboluminescent, it is enough to hit pieces of quartz in the darkness to corroborate this. Many minerals are thermoluminescent, i.e., they emit light when heated above a certain temperature.

Let's consider the phenomenon of mineral fluorescence. It is a kind of interchange by which some minerals receiving radiation in a certain range of wavelengths (for instance, ultraviolet radiation) are able to temporarily absorb a small amount of this radiation and, an instant later, release it in a different wavelength. This process of action and reaction is already an elementary kind of semiosis (that we could consider to be of an indexical nature) involving an exchange between non-living entities, such as light and minerals.

Nöth and Kull echo this idea of extended semiosis, encompassing the animate life and the "inanimate" world:

> In contrast to the cultural semiotic perspective of nature, the perspective of general semiotics investigates sign processes in nature as semiotic processes sui generis. Foundations of this tradition have been laid by C. S. Peirce, C. Morris, and T. A. Sebeok, and on the basis of this broader concept of semiotics, new fields of semiotic research have been explored during the last decades, which have led to a considerable extension of the field of semiotic research. Semiotics is no longer only concerned with signs that depend on culture and cultural codes, since it has advanced to a theory of sign processes in culture and in nature. Contributions to this extension of the semiotic field come from the history of semiotics with its long tradition of the study of natural signs, which were sometimes defined in sharp opposition to other signs, but sometimes as a branch of the general theory of signs. Research in zoosemiotics and biosemiotics has proceeded with the lowering of the semiotic threshold from human semiosis to semiotic processes whose agents are animals and micro-organisms, in fact all living cells. More recently, the question has been raised whether precursors of semiosis should even be sought in the inanimate or prebiotic world and whether semiotics should also include the field of physicosemiotics: autocatalytic systems, dissipative structures, and other processes in dynamic physical systems, which testify to the possibility of a spontaneous increase of order in nature, and accordingly become the topics of study in the search for the origins of semiosis in a field of protosemiotic studies. (Nöth and Kull 2001)

While Thomas Sebeok has been a pioneer in expanding the sphere of semiotics to animal semiosis, by coining the term "zoosemiosis" in the sixties, while he also recognizes Martin Krampen for having introduced phytosemiosis (Sebeok 1991: 14), and while he accepts that in each of the kingdoms of biology "distinct but intertwined modes of semiosis have evolved" (Sebeok 1991: 89), he seems reluctant to accept that the action of signs can be extended to non-living entities. According to Sebeok, the universe:

> was dominated by the influence of photons (heat and light). The elementary particles multiplied, matter became ordered, and the Universe organized itself into ever more complex systems. The quasi-semiotic phenomena of nonbiological atomic interactions and, later, those of inorganic molecules, were consigned by the late oncologist Prodi (1977) to "protosemiotics", but this must surely be read as a metaphorical expression. (Sebeok 1991: 84)[1]

The proposal of the present paper, instead, is that we could speak of semiosis in all orders of nature, even considering the traditional (and obsolete) divisions among animals, plants, and minerals. We can reach the conclusion that if there is semiosis in the animal world, there should also be semiosis in the world of plants and in the mineral world. But, if in addition to this we postulate that a sharp division among these worlds cannot be established, this reinforces the idea that a sharp division among levels of semiosis cannot exist either. Semiosis, or semiotic activity, would be equivalent to life (biosemiosis) – but we can extend the concept also to the interaction among objects that are usually termed inanimate or inert because it is not so clear that they really are so, as if they were totally devoid of some force or activity. If so, how did the universe (which eventually gave rise to life on a planet where conditions were favorable) begin?

Some people differentiate intelligent life (as if it were only a property of humans) from non intelligent life, vegetative life, etc. I argue that one could say that all kinds of life are "intelligent," otherwise they cannot manage to evolve. Applying the concept of evolution, we certainly must go back to the origins of the Earth, and even to the origins of the universe.

Obviously, there are more complex, evolved, or elaborate levels of semiosis (for instance, human semiosis), as it is true that there are levels of intelligence, not only among different species but even inside the same species. Or, not to put it simply in quantitative terms, we can argue that there are different forms of intelligence, some of them more productive and useful in one sense, some others better or more useful in other sense.

In this way, the use of signs appears in all orders, "upper" and "lower," in the biotic world (biosemiosis) but also in the abiotic nature (physiosemiosis), if it is possible to keep with this division anyway.

Let's analyze the concept of sign in the light of these ideas, in order to see if we can really consider that there is signic activity even in the farthest orders from what is usually considered "life."

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1 Sebeok refers to Giorgio Prodi and his book *Le basi materiali della significazione* (Milan: Bompiani, 1977). An English article on this subject was published by Prodi as "Material bases of signification" in *Semiotica* 69 (1988), 191–241.

According to Peirce, a sign is something (a representamen) that stands for some other thing (the object) for something (the interpretant). This "something," or the interpretant, is not necessarily to be understood as a living being or a person, but simply as a third thing: the interpretant is also a sign, another sign. If in some order of entities this process is verified, where a "first" substitutes or represents a "second" for a "third," then we are facing semiosis. It does not matter whether these entities are living beings or not (according to the present criteria of classification, that could certainly become obsolete or imprecise if instead of divisions we have rather gradations, as we have seen).

In addition to being a matter of gradation by means of an evolutionary process, the fact that something can become different from another thing and generate a new category can be also a matter of scale. Dardo Bardier develops this concept in his book *Scales of Reality* (Bardier 2007). We think of minerals as inert or inanimate objects (devoid of movement of their own) because we compare them in terms of a temporal scale that is perceptible to us: the span of our own life, for instance. Evidently, in this scale of time changes within "inert" matter cannot be observed. But if we think of minerals in terms of thousand of million years (the lifetime of the Earth), nothing stable or "inert" seems to exist. Rocks are conglomerates of substances fused in some way. Is the chemistry of these elements keeping completely stable? Is the rock that we find today, which could be dated to three thousand million years (by means of the method of uranium-lead radiometric dating), the same rock that it was three thousand million years ago, when it was formed? Evidently, it is an "older" rock, i.e., it contains some index by which its "age" can be dated. This index of "aging" is something that kept slowly changing along millions of years, which is present in the same rock.

Scientists do not hesitate to speak of the "age" of our Earth. Certainly, the Earth is a very complex "organism," even more complex than the most evolved of present mammals, the human being, because the Earth is not just a conglomerate of minerals and water. Vegetal and animal organisms that live on Earth are part of it. It is the Earth that gave origin to them, that sustains their lives, that provides the aliments to them (water, air, light, nutrients, food), and finally that receives their waste matters, both in life and after death. Such waste matters become part of the planet, and even are transformed into coal, oil, gas, etc.

Why not apply the same temporal category to minerals in general? If the Earth started by simply being a piece of rock expelled from an explosion or a big collision in the solar system and became an organism of such a big complexity

as it is after 4,560 millions of years (the Earth's age, as calculated at present), potentially other pieces of rock could suffer a similar fate.

In all the processes described, semiosis in relation to visible radiation is of primordial importance. The incandescence of gas or matter produces luminous radiation. All objects and living beings interact in some way or another with this radiation. Among minerals, it produces certain reactions and changes, as well as in plants, for which it is a vital element. In animals, it has generated the vision systems, which react to luminous stimuli, obtain information, live and evolve from making some semiotic interchanges with light. We must keep in mind that luminous radiation is the physical agent that permeates the whole universe. Thus, the relevant question that relates vision and knowledge should not be limited to human knowledge.

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Bionote

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Jose Luis Caivano is a professor at the University of Buenos Aires, Faculty of Architecture; director of the Research Program on Color and Visual Semiotics. He has published 2 books as author, 12 books as editor, and more than 100 articles in international journals such as *Color Research and Application, Die Farbe, Colour: Design & Creativity, Leonardo, Semiotica, Visio*, and others.