CHAPTER 7

BIOSEMIOTICS AND BIOPHYSICS — THE FUNDAMENTAL APPROACHES TO THE STUDY OF LIFE

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Abstract: The importance, scope, and goals of semiotics can be compared to the ones of physics. These represent two principal ways of approaching the world scientifically. Physics is a study of quantities, whereas semiotics is a study of diversity. Physics is about natural laws, while semiotics is about code processes. Semiotic models can describe features that are beyond the reach of physical models due to the more restricted methodological requirements of the latter. The "measuring devices" of semiotics are alive — which is a *sine qua non* for the presence of meanings. Thus, the two principal ways to scientifically approach living systems are biophysics and biosemiotics. Accordingly, semiotic (including biosemiotic) systems can be studied both physically (e.g., using statistical methods) and semiotically (e.g., focusing on the uniqueness of the system). The principle of code plurality as a generalization of the code duality principle is formulated

Physical or natural-scientific methodology sets certain limits to the acceptable ways of acquiring knowledge. The more alive the object of study, the more restrictive are these limits. Therefore, there exists the space for another methodology – the semiotic methodology that can study the qualitative diversity and meaningfulness of the world of life.

THE DEVELOPMENT (OR SPECIATION) THAT HAS RESULTED IN BIOSEMIOTICS

An analysis of the early development of the approach that is nowadays called biosemiotics shows that it has emerged from several trends and branches concerned with the study of life processes. There are three main approaches.[1]

1. The *Holistic* approach in biology treats biological phenomena and organic forms as functional parts of organic wholes. Relatedness to the wholes is thus opposed

M. Barbieri (ed.), Introduction to Biosemiotics, 167–177.

to reductionism that explains the structures on the basis of constituent elements of these structures.

2. The *Structuralist* approach, or study of the specifically biological rules has often demonstrated the autonomy of these rules which means that these rules cannot be deduced from general physical or chemical laws. Biological rules, or organic codes, are historically and locally generated, thus providing a certain natural analogy to the codes of cultures.
3. The *Communicational* approach, including the study of animal communication, follows the models of communication worked out as models of sign communication. Particularly, the general semiotic theory of Charles Morris (1971) includes the communication of non-human animals as a form of sign communication. A more systematic review of the forms of animal communication has been compiled by Thomas Sebeok (1977).

In theoretical biology, at least since Karl Ernst von Baer's "*Welche Auffassung der lebenden Natur ist die richige*?" (Baer 1864), a trend (or paradigm) has developed which seeks the construction of an extended biology, one that could deal with both subjectivity and meaning. One may include in this trend: Nicolas Rashevsky's idea of relational biology, Brian Goodwin's idea of organisms as hypothesis testing systems (Goodwin 1972: 267), Howard Pattee's idea of self-interpretation as the basis of life (Pattee 1972: 249), Robert Rosen's analysis of the dualism between quantitative and qualitative (Rosen 1991).

A special place in the history of biosemiotics belongs to Jakob von Uexküll. In his *Theoretische Biologie* (1928) and particularly in *Bedeutungslehre* (1940) he developed an approach that could encompass the kind of subjectivity that every organism possesses in its unique relationship to its world (Deely 2004; Rüting 2004; Kull 2001).

More recently there has been research on the parallels of non-verbal communication in animals, which led to the formulation of zoosemiotics by Thomas A. Sebeok since 1963 (Sebeok 1972; 1990).

Another addition to the field, endosemiotics, developed from the study of the communicative nature of many intraorganismic relationships (T. Uexküll et al. 1993), led to the placing of a semiotic threshold[2] at the border of life (Anderson *et al.* 1984; Sebeok 2001). The latter would mean that the sphere of sign processes, or semioses, corresponds with the sphere of living processes. Thus, semiosphere — the notion introduced by Juri Lotman — coincides with the biosphere (Lotman 1990; 2005; Kotov, Kull 2006). Or, as it has been put by T. A. Sebeok — life and semiosis are one and the same (Sebeok 2002).

Biosemiotics is deeply rooted both in (the holistic, epigenetic, organicist) biology, and in semiotics proper. Of the semioticians, whose work and concepts have been particularly important for biology, one should mention Charles S. Peirce (Santaella 1999), Charles Morris (Petrilli 1999), Roman Jakobson (Shintani 1999), Juri Lotman (Kull 1999c), and again Thomas A. Sebeok (Deely 2005b; Kull 2003).

The term 'biosemiotics' probably appeared for the first time in an article by Friedrich S. Rothschild (1962).[3] Books under this title started to appear since 1992

(Sebeok, Umiker-Sebeok, 1992), and international annual meetings ('Gatherings in Biosemiotics') have been organized regularly since 2001 (however, the history of international biosemiotic meetings dates back at least to 1978). The 'International Society for Biosemiotic Studies'[4] was established in 2005, and the *Journal of Biosemiotics* began in the same year.

This convergence of sources has created a dynamic approach that tends to reshape biology — this can be seen in a series of texts written in the past decade, including books (Hoffmeyer 1996; Deacon 1997; Sebeok 2000a; Emmeche et al. 2002; Markos 2002; Barbieri 2003; Weber 2003; Schult 2004; Witzany 2006; etc.), special issues of journals (e.g., *Semiotica* 127(1/4), 1999; 134(1/4), 2001; *Sign Systems Studies* 30(1), 2002; 32(1/2), 2004; *Cybernetics and Human Knowing* 10(1), 2003; etc.), and a large number of single articles.

It can be argued that the whole domain of biology — the study of living systems — belongs to the domain of semiotics. However, living systems are simultaneously a special type of physical systems (the self-organizing, locally autocatalytic, complex dynamic systems) — which means that the whole domain of biology simultaneously belongs to the domain of physics. This paradoxical relationship between semiotic and physical approaches also poses the greatest methodological problem in the life sciences.

SEMIOTICS AND PHYSICS

Roland Posner, in his Presidential address in Semiotics Congress, 2000, in Dresden, has characterized "semiotics as the physics of the XXI century" (Posner 2001). This underlines that semiotics is not only an alternative, but also similar to physics in its role, universality, and theoretical depth. Such a comparison between physics and semiotics is not new.

John Locke, in *An Essay Concerning Human Understanding* (1690), argued that all human knowledge can be divided into three major sciences, into three 'sorts of sciences' — ethics, physics, and semiotics.[5] As he said, "This is the first and most general division of the objects of our understanding". Leaving aside the analysis of the domain of ethics, our task here is to describe the divide between physics and semiotics, and by doing so help clarify the basic differences between the physical (or natural-scientific) and semiotic biology.

Both physics and semiotics have expressed their ambition to be able to deal with everything in the world. However, the world either as a whole, or as a space is described quite differently by these two transdisciplinary sciences.

When speaking about the semiosphere as the space of meaning-generation — or semiosphere as a continuum of life — it would be helpful to distinguish it from space that is not (part of the) semiosphere. For instance — atmosphere is obviously not semiosphere. Similarly, whenever a semiotician uses the expression "purely physical" we should realise that he or she is in the majority of cases not referring to something belonging to the semiosphere. Thus it is reasonable to ask

Table 1. Interrelation of semiotic/non-semiotic methods and semiotic/non-semiotic things as generating a principal classification of sciences

Things \ Methodologies	Non-semiotic (detextualised) approach	Semiotic (textualised) approach
Non-semiotic (not alive)	physics *s. str*.	Ecosemiotics *s. str*., semiotics of environment
		Primary semiotic threshold
Semiotic (alive)	biology *s. str*. — physical or natural-scientific biology	Biosemiotics, including endosemiotics, zoosemiotics, etc.
		Secondary semiotic threshold
Semiotic (lingual)	sociology *s. str*.	Semiotics of culture

what is the difference between physical space (physical world) and semiotic space (or semiosphere).

It is useful to remember that 'semiotic' means both an approach and an object — likewise, 'physical' means both an approach and an object. In addition to the study of semiotic processes or semioses (i.e., semiotics *s. str*., including semiotics of culture and biosemiotics), there also exists a semiotic study of the environment that is not necessarily a living one or semiotic *per se* (this environment is studied, e.g., by ecosemiotics, or semiotics of environment), which means the textualization (or rather signification) of everything, independent of its nature (Nöth 2001). Besides the study of non-semiotic (or study of everything as "meaningless", as in physics), there also exists a non-semiotic approach to the living, i.e. a physical study of semiosis-consisting or self-defining objects (examples of this approach include large part of biology, and the natural-scientific study of society) (Table 1).

This classification follows from the nature of semiosis that locally multiplies the reality. Consequently, semiosphere can be viewed as the region of multiple realities. However, the region and phenomena of multiple realities can be described as all belonging to one single reality (as in the physical approach). Furthermore, the regions of single reality can be projected into the multiple one via the description process itself (like semiotics does). Therefore, four groups of sciences can be distinguished in this respect (Table 2).

Table 2. Projections of realities from two types of world (of one or several realities) into two types of models (of descriptions in a single or multiple languages) as a basis for classification of sciences

World \ Models	Non-semiotic models	Semiotic models
Non-semiotic (world of no semiosis)	Single reality into Single reality	Single reality into Multiple realities
Semiotic (world of semioses)	Multiple realities into Single reality	Multiple realities into Multiple realities

These four basic types of modeling differ also in the sense of simplification. One can claim that any modeling simplifies, however, in a more general sense, physics of *physis* (upper left in the Table 2) and semiotics of *semiosis* (bottom right in the Table 2, both biosemiotics and semiotics of culture in Table 1) tend not to make dimensional simplification, whereas physics of semiosis (bottom left, both natural-scientific biology and sociology in Table 1) does, and semiotics of non-semiosis (upper right — 'physiosemiotics') adds some dimensions when textualizing non-signs.[6]

The two principal types of inquiries, or classes of sciences — *physica et semiotica* — provide two distinct types of descriptions. A brief comparison of these two points of view is presented in Table 3.

Both physics and semiotics have expressed their ambition to study everything in the world, or at least their ability to cover everything. These can be seen as different types of sciences, approaches, or points of view. In principle, any phenomenon can be studied both physically and semiotically.

From Table 3 it appears to be quite clear that the difference between physics and semiotics, when studying seemingly one and the same thing, is rooted in their methodology. Physics and semiotics, are just two different ways of seeing the same world, each with their own separate point of view[9] — and set of methods. They differ on how the world is perceived; in the case of physics there exists just

Table 3. Relationships between the two types of transdisciplinary sciences — physical, and semiotic.

	Physics	Semiotics
Study fields, e.g.	natural sciences	sciences of meaning
	study of quantities	study of qualitative diversity
	physical ecology	semiotic ecology
	biophysics	biosemiotics
Objects (models) of study	physical space	semiotic space, semiosphere
	non-textual or detextualised	textual or textualised
	things and interactions	signs and semioses[7]
	laws	codes, habits
	transformations	translations, interpretations
	quantities	qualitative diversity
	multiple objects	*unique* objects
	world as non-living	living world
Features of objects (models)	commensurability	incommensurability
	context-independence	context-dependence
	errorless nature	Fallibilism
Methods of study	measurements	qualitative methods
	experimental	experiential
	from outside	from inside
	by independent researcher	participatory study
	reductionism	holism, mimesis[8]
	statistical tests	comparisons
Truth, reality	*single*	*plural*

a single physical world that is studied via repetitiveness (both of its elements and of the measurements), whereas in the case of semiotics there exist many individual (subjective) worlds each requiring different approaches. Semiotics therefore covers an area (multiple or plural realities of life) which is inaccessible to physics, because by its very definition, physics requires repeatability and abhors uniqueness.

Hence, we may study the physics of an organism, and alternatively, we may study the semiotics of an organism. The former is about many things (its mechanics, dynamics, chemistry), but not about meanings. The latter is the study in terms of semiotic space, and consequently emerging meanings can be studied. Likewise, Yoshimi Kawade (1999: 370) has distinguished between 'physicobiology' and 'semiobiology'.

It is important to note that both — physics and semiotics — make predictions. However, the methods of making these predictions are principally different. The physical types of predictions are quantitative — either deterministic, probabilistic, or statistical. Semiotic predictions however are qualitative ones. For instance, when studying a text that is currently in the process of being written, it is possible to make a scientific prediction about the next word to appear. In the case of a physical approach, the prediction would use correlations between adjacent words in the language, and it will be possible to calculate the statistical probabilities for the next word. A semiotic approach, on the other hand, would look at the possible meanings of the expression, and provide a prediction about the next word on a purely qualitative basis.

When speaking about the environment and ecology in this context, one realises that ecology is clearly twofold. There is an ecology that has been developed as a natural science, i.e., according to the Modernist model of science — a field of quantitative research of environment with organic systems in it, without any intrinsic value or meaning in itself. This can be seen as a branch of physics, or biophysics. And there is an ecology that includes meaning and value — ecophilosophy, biosemiotics, semiotic ecology — which is a branch of semiotics. The latter has been characterized as belonging to the post-Modern approach (Deely 2005a; M. Lotman 2002).

The environment as a physical concept, it should be emphasized, is not the same as semiosphere. But it is however permissible to view the ecosphere as a semiotic concept. According to biosemiotics, the concept of the semiosphere is synonymous with ecosphere. Therefore, this is a concept that can deal with environmental problems without the nature-culture opposition; instead, these problems can be formulated in terms of specific features of sign systems.

Here we should also mention *umwelt* — a concept introduced by Jakob von Uexküll — and closely allied to the notion of semiosphere. We may redefine it: *umwelt* is a personal semiotic space. Thus — *Umweltforschung*, or *umwelt*-research is a semiotic study. From the above we can see that it is conceivable to have parallel approaches to the environment, one in which meaning is generated, the other the more traditional quantitative approach.

Of course — the issue is more complicated, because one can distinguish between physical and semiotic *things*, physical and semiotic *methods or approaches*, and physical and semiotic *models and knowledge.*

Since the semiosphere, being a concept or model belongs to semiotic knowledge, then evidently we can speak about semiosphere everywhere semiotic knowledge extends. Conversely, everything physical is capable of being textualised, and physical models can be seen (interpreted) as special cases of semiotic ones.

If we look at the level of methods, it turns out that the physical method is restricted – it is incapable of discovering meaning or meaningfulness. In order to detect meaning, we need a semiotic approach. One needs a "living device", because meaning is exclusive to living beings. Thus — semiosphere is a creation or a construct of the semiotic method.

The world of signs is formed by those who are capable of making differences. The power of distinction-making is, in a way, also a method. Only those who use several codes, several sign systems, etc., can be a part of the semiotic world, the semiosphere.

The acceptance of two fundamental methodologies — physical monism and semiotic (realist) pluralism — can be described as the methodological duality. Because these, indeed, are complementary to each other, they can co-exist. Their co-existence, however, requires a "bridge", and this, again, can be provided by semiotics — as claimed, e.g., by Yates (1985), Perron et al. (2000), Sebeok (2000b).

THE PRINCIPLE OF CODE PLURALITY

Mind is never single, in the sense of how the physical world is viewed — there are always many minds. Even in ones own mind, there exists a multitude of mind-creating semioses, since mind is in effect an intersection of codes.

Hoffmeyer and Emmeche (1991) have cogently argued that life can only be understood as including two codes — the digital and the analogue. Or — *at least* two codes, as stated by Juri Lotman (1990; 1992).

In one of his articles, Claus Emmeche (2004) speaks about the code plurality, in the sense that there are many codes in any living organism:

> A biological notion of *function* is not a part of physics, while it is crucial for all biology. Biofunctionality is not possible unless a living system is self-organizing in a very specific way, based upon a memory of how to make components of the system that meet the requirement of a functional (autopoietic and homeostatic) metabolism of high specificity. For Earthly creatures this principle is instantiated as *a code-plurality* between a 'digital' genetic code of DNA, a dynamic regulatory code of RNA (and other factors as well), and a dynamic mode of metabolism involving molecular recognition networks of proteins and other components. (Emmeche 2004: 120)

This feature — of the necessary co-existence of many codes — however, is far more general. As it characterizes all life processes, it also characterizes any sign process.

Consequently, we can formulate this as the *principle of code plurality* — which states that any text, any sign, any semiosis assumes the co-existence of several codes, of many codes.

Semiosphere is the web of interpretations and reinterpretations. Every text is written by many, and read by many. Any piece of biosphere, any site in culture is reshaped and recognized by many.

Likewise to the semiosphere, one can characterize the organism or organic "body as a web of semioses" (T. von Uexküll et al. 1993: 9). Further, any organic whole — for instance, biological species as a self-defining category — is not real, strictly speaking, from the physical point of view. Still, biological species are real, however, in a certain fuzzy way. This "fuzziness" is an apt description of its indeterminate reality, because the species (any biological species, as well as any organic, perceptual etc. category) is a creation of multiple recognition-representation processes of the organisms (or the cells, etc.) that together make the species — a multi-real entity.

The models of communication that characterize the communication process as a dialogue, a movement of messages between two, consequently, oversimplify the situation, because any communication is communication between many. Accordingly, the principle of code plurality implies the fundamental communication model of many-to-many.

Semiosis is the process which both creates the realities and connects them. Since, according to the semiotic approach, "what is important in biology is not how we see the systems which are interacting, but how they see each other" (Rosen et al. 1979: 87), therefore there are always many realities, many descriptions. This can be derived from the multitude of umwelten, or from the co-existence of both synchronic and diachronic semiosis, or from the multitude of the levels of self-representation.

Robert Rosen has noted that, "so long as we persist in equating mechanism with objectivity, and hence with science, the mind-brain problem and, even more, the life-organism problem are inherently outside the reach of that science" (Rosen 1999: 94). The enlargement of objectivity that would lead to the solution of these problems, cannot be less radical than the abandonment of the assumption of the unity of the reality and the acceptance of realist pluralism. *Meaning is plurality*. The difficulty of the mind-body problem has been very much rooted — and known since Aristotle — in the assumption about a certain primary equivalence of the minds or mental experiences. A version of such equivalence is represented by dualism. The similarity of minds, however, is secondary, it is a result and construct of their communication. This is why the concept of sign processes, semioses, resolves the mind-body problem.

BIOSEMIOTICS AND BIOPHYSICS: INSTEAD OF CONCLUSION

Robert Rosen (1999: 105) has said that "Life poses the most serious kinds of challenges to physics itself". His approach has demonstrated a way in which the understanding of life processes requires the assumptions that create the models beyond physical ones.

In order to understand the scope, role, and tasks of biosemiotics, it is obviously necessary to describe its framework, to compare it with other approaches.

Biosemiotics, on the one hand, is semiotic methodology as applied to the study of living systems. On the other hand, biosemiotics means the study of living systems that interprets these as sign systems, or communicative structures, and involves the description and analysis of various organic codes (e.g., epigenetic, genetic, behavioural codes, including intracellular, intercellular, and interorganismic codes). Important examples include the immunological code, and ecological code (e.g., Levich, Lovyagin 1977). Biosemiotics comprises of a rich set of processes and phenomena, categories and categorization that are achievable via the multiple descriptions using different means and languages of description.

The conclusion of our analysis demonstrates that biosemiotics stands simultaneously in three different relationships with biophysics (a) biosemiotics is opposed to biophysics, (b) biosemiotics is more general than biophysics, (c) biosemiotics is more specific than biophysics.

Thus, this adds an additional meaning to the formulation expressed by Jesper Hoffmeyer (1997): "Rather than understanding biology as a separate layer 'between' physics and semiotics, we should then see biology as a science of the interface in which these two sciences meets, an interface in which we study the origin and evolution of sign processes, semiosis."

If biophysical modeling is the highest achievement of modernist biology, then biosemiotics must be the biology of the post-modern era.

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NOTES

[1] A more detailed history of biosemiotics is described in Favareau (2006) and Kull (1999a); also in *Journal of Biosemiotics* 1(1): 1–25 (2005).

[2] The term 'semiotic threshold' has been introduced by Umberto *Eco* (1979). He wrote: 'By *natural boundaries* I mean principally those beyond which a semiotic approach cannot go; for there is non-semiotic territory since there are phenomena that cannot be taken as sign-functions' (Eco 1979: 6).

[3] Though, in the form of 'biosemiotic'. About Rothschild's work, see Anderson (2003), Kull (1999b).

[4] See its homepage at http://www.biosemiotics.org/.

[5] See Deely 2001: 593ff.

[6] It is also important to distinguish between the textualization (thus semiotization) of non-living world, and the semiotics of the study of the non-living world, e.g., semiotics of physics, or semiotics of chemistry (cf., e.g., Hoffmann 1995; Pirner 2002; Yates, Beaugrande 1990).

[7] Or *objects*, in the sense of Deely 2005.

[8] The role of mimesis as a study method apposed to reductionism has been described by Rosen 1999; 116ff.

[9] Cf. Deely 2005: 12ff.

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