Biosemiotics in the twentieth century: A view from biology

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> Den Lebens-Prozess ... halten wir nicht für ein Resultat des organischen Baues, sondern für den Rhythmus, gleichsam die Melodie, nach welcher der organische Körper sich aufbaut und umbaut. (von Baer 1864: 280)
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> Symphony or embryo, the principle is the same: the more complex the pattern, the more important the silences. (Pollack 1994: 76)

This article attempts to touch on some contexts and associations of the semiotic view in biology, by making a short review of the history of the trends and ideas of biosemiotics, or semiotic biology, in parallel with theoretical biology, over a one-century period, as viewed from the side of biology.[1] The latter is an important restriction, since the picture may look considerably different from the viewpoint of and within the context of semiotics. It is important to emphasize this since biosemiotics, although now accepted as a distinct branch in semiotics, has still not found its place in biology. For instance, one can find chapters devoted to biosemiotics in contemporary semiotics textbooks, and corresponding sections in large semiotics conferences, whereas the same is quite rare in biological (or even ethological) reviews or congresses. However, the situation today is already different from that of a decade ago, when D. Todt (1987) and J. Schult (1989: 261) claimed: 'Es ist ohne jeden Zweifel so, daß ... die Semiotik bisher in die Biologie kaum Eingang gefunden hat'. According to J. Deely (1990: 25), 'the introduction of symbiosis and reciprocity into the heart of the evolutionary process along with the selection of mutations, makes of these new concepts an extremely fertile ground for the further development of semiotic consciousness, and an inevitable frontier that semiotic theory cannot for long delay exploring'.

Delimiting the period to one century also means that, according to the approach used in this article and the meaning given here to the notion

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'biosemiotics', this branch of science or a corresponding approach may, under some other name, have existed before this period (e.g., Sebeok 1996 has described it in the example of the works of Galen), and will exist after it. Such a situation is certainly common for many — if not for almost all — sciences. The fact that I have not seen comprehensive analyses of the history of theoretical biology, despite of its rapid development in this century, is an additional hurdle to the making of this analysis.

Approaches

Biosemiotics can be defined as the science of signs in living systems. A principal and distinctive characteristic of semiotic biology lies in the understanding that in living, entities do not interact like mechanical bodies, but rather as messages, or pieces of text. This means that the whole determinism is of another type. Semiotic interactions do not take place of physical necessity (however, not contradicting this, or as stated by W. Elsasser [1982]: laws of quantum mechanics hold), but because some of the interactors have learned to do so (using the notion of 'learning' in a broad sense here). The phenomena of recognition, memory, categorization, mimicry, learning, and communication are thus among those of interest for biosemiotic research, together with the analysis of the application of the tools and notions of semiotics (text, translation, interpretation, semiosis, types of sign, meaning) in the biological realm. However, what makes biosemiotics important and interesting for science in general is its attempt to research the origins of semiotic phenomena and, together with it, to pave a way of conjoining humanities with natural sciences, culture with nature, through the proper understanding of the relationships between 'external and internal nature' (Hoffmeyer 1993: 155).

Biosemiotics has been declared a (new) paradigm for biology (or theoretical biology) in several articles (Anderson et al. 1984; Hoffmeyer and Emmeche 1991; Eder and Rembold 1992; Kull 1993a; cf. Anderson 1990). 'What we propose, then, is that the traditional paradigm of biology be substituted by *a semiotic paradigm* the core of which is that *biological form is understood primarily as sign*' (Hoffmeyer and Emmeche 1991: 138). Therefore, biosemiotics can be seen not only as a branch of semiotics, but also as an approach in theoretical biology.

Even by the proponents of biosemiotics, the relationship between semiotics and biology has been viewed in various slightly different ways. Let me list some of them, using longer quotations to show the variability of views.

(1) M. Florkin (1974), an author of a pioneering work on intracellular semiotics, wrote: 'Molecular biosemiotics is an aspect, not of human sciences, but of molecular biology. As stated by De Saussure, in linguistics, the sign which he considers as the association of a significant and signified, is arbitrary with reference to the relation between its two faces. In molecular biosemiotics, on the other hand, significant and signified are in a necessary relation imposed by the natural relations of material realities' (1974: 14). 'We find it advisable to avoid the application of the *specific* concepts of linguistics (word, phrase, etc.) to biosemiotics and, however tempting it may be, to decide not to introduce such expressions into it' (1974: 13). 'We believe that in future development, linguistic semiology will become based on molecular biosemiotics of the activities of the brain. We shall therefore use in the perspective of this subject several general concepts elaborated by De Saussure such as significant and signified, synchrony and diachrony, syntagm and system with the special meaning they have in molecular biosemiotics. It must be noted that in the mind of F. de Saussure these concepts arose from the consideration of existential (not psychological) aspects of natural science. ... It is therefore fitting to situate these concepts in the most general context of semiotics, the general science of signification, of which linguistics and biosemiotics are special aspects' (1974: 14).

(2) Sebeok (1991: 22) sees in biology a good part of semiotics: 'The process of message exchanges, or *semiosis*, is an indispensable characteristic of all terrestrial life forms. It is this capacity for containing, replicating, and expressing messages, of extracting their signification, that, in fact, distinguishes them more from the nonliving — except for human agents, such as computers or robots, that can be programmed to simulate communication — than any other traits often cited. The study of the twin processes of communication and signification can be regarded as ultimately a branch of the life science, or as belonging in large part to nature, in some part to culture, which is, of course, also a part of nature'. 'The life science and the sign science thus mutually imply one another' (Sebeok 1994: 114).

(3) Pattee (1997) approaches it from the standpoint of physical biology: 'Physical laws and semiotic controls require disjoint, complementary modes of conceptualization and description. Laws are global and inexorable. Controls are local and conditional. Life originated with semiotic controls. Semiotic controls require measurement, memory, and selection, none of which are functionally describable by physical

laws that, unlike semiotic systems, are based on energy, time, and rates of change. However, they are structurally describable in the language of physics in terms of nonintegrable constraints, energy degenerate states, temporal incoherence, and irreversible dissipative events. A fundamental issue in physics, biology, and cognitive science is where to draw the necessary epistemic cut between the coherent physical dynamics and its rate-independent semiotic description. To function efficiently, semiotic controls at all levels must provide simple descriptions of the complex dynamical behavior of the input/output systems we call sensors, feature detectors, pattern recognizers, measuring devices, transducers, constructors, and actuators'.

(4) Hoffmeyer (1997) proposes the synthesis and reformulation of evolutionary theory and ecology through semiotics: 'A modern unification of biology ... has to be based on the fundamentally semiotic nature of life'. And elsewhere: 'It has to master a set of signs, of a visual, acoustic, olfactory, tactile, and chemical nature, by means of which it can control its survival in the semiosphere. ... The semiotic demands made on an organism are vital to its success. ... One can never hope to understand the dynamic of the ecosystem without allowing for some form of *umwelt* theory' (Hoffmeyer 1996a: 59). 'The most pronounced feature of organic evolution is not the creation of a multiplicity of amazing morphological structures, but the general expansion of "semiotic freedom", that is to say the increase in richness or "depth" of meaning that can be communicated' (1996a: 61). 'The sign rather than the molecule is the basic unit for studying life' (Hoffmeyer 1995: 369).

(5) Emmeche (1992: 78) has delimited the field of biosemiotics as follows. '*Biosemiotics* proper deals with sign processes in nature in all dimensions, including (1) the emergence of semiosis in nature, which may coincide with or anticipate the emergence of living cells; (2) the natural history of signs; (3) the 'horizontal' aspects of semiosis in the ontogeny of organisms, in plant and animal communication, and in inner sign functions in the immune and nervous systems; and (4) the semiotics of cognition and language. ... Biosemiotics can be seen as a contribution to a general theory of evolution, involving a synthesis of different disciplines. It is a branch of general semiotics, but the existence of signs in its subject matter is not necessarily presupposed, insofar as the origin of semiosis in the universe is one of the riddles to be solved'.

(6) Salthe (1997) sees the whole of biology as a semiotic process: 'On the use of semiotics, ... I am taking off from a more ontologically involved stance than Hoffmeyer and Emmeche. Biology ... becomes

one thread in society's entanglements with the world, rather than a compartment of sure knowledge'. 'The system of interpretance is the discourse of biology'. And elsewhere (Salthe 1993a: 15): 'Adaptation by natural selection is a semiotic fine-tuning. The lineage ... reads the environment through adaptations, which are signs of it. And, since anything can be an adaptation to any environment problem ..., these signs are purely symbolic'.

(7) Chebanov (1994: 40) has ascribed the greatest importance to the aspect of interpretation. 'Now, while the hermeneutization of humanitarian disciplines is being developed and some domains of biosemiotics appear to be involved in it, I find sufficient reasons to call this trend "biohermeneutics" *sensu lato*. ... The object of biohermeneutic studies is the semiotic aspect of Living Being as centaurus-object. ... Somatic and physiological organization of Living Being is functioning as semantophore, i.e. as an exponent of semiotic means, whose nature or the substratum is important for its semiotic performance'.

Beginning of the century

To understand the atmosphere in biology in von Uexküll's time, it is important to note that the decades around the turn of the century were very productive in starting simultaneously a series of new branches in biological research. Among them, the following can be listed:

(1) beginning of genetics through the rediscovery of Mendel's laws;
(2) beginning of mathematical biology and research into population variability, under the name of biometry (K. Pearson); the establishment of the first journal (*Biometrika*) in this field (1901–1902);
(3) beginning of biophysics (D'Arsonval et al. 1901);
(4) the first book with the title 'theoretical biology' (Reinke 1901);
(5) the boom of neovitalism (H. Driesch);
(6) intensive work in the field of morphogenesis (W. Roux's *Entwickelungsmechanik*);
(7) also, ecology as an independent science took its first steps.

All these events had a long-lasting effect on biology, and considerably influenced theoretical discussions in biology. We may say, I suppose, that at that time theoretical biology as a branch of biology was born. Before that time there existed works which can be classified as theoretical biology, but as a branch with its specialized journals, books, name, and devoted specialists, it did not exist. This period of intensive diversification in biology at the turn of the century is somewhat comparable to the great peak in theoretical biology which took place in the 1960s and 1970s.

Jakob von Uexküll (1864–1944), who developed one of the first comprehensive systems of notions for semiotic biology, was probably the most important figure in biosemiotics in the first half of the twentieth century. His books *Umwelt und Innenwelt der Tiere* (1909), *Bausteine zu einer biologischen Weltanschauung* (1913), *Theoretische Biologie* (1920a, 1928), and *Bedeutungslehre* (1940); his popular scientific books *Biologische Briefe an eine Dame* (1920b) and *Streifzüge durch die Umwelten von Tieren und Menschen* (J. von Uexküll and Kriszat 1934); and his many articles introduced an approach and terminology which was for a long time used and accepted only by a small group of scientists, but now (particularly in the last decade) has found rapidly spreading use in the works of semioticians and also in those of some psychologists, anthropologists, ecologists, philosophers, and computer scientists. It should also be considered that von Uexküll was, primarily, a biologist who was not content with the commonly used level of scientific argumentation, and decided to place biology on a solid philosophical basis.

J. von Uexküll has stressed that his approach is a development of the views of German physiologist Johannes Müller (1801–1858), whose law of specific sensory energies states that 'the modality of the sensation depends in an immediate manner only upon what region of the central organ is put into a corresponding excited state, independent of the external causes bringing about the excitation' (Schlick 1977: 165). Or, as formulated by von Uexküll (1931a: 209): 'Eine lebende Zelle besitzt ihren eigenen Ichton'. As a philosophical background, von Uexküll applied the epistemology of I. Kant to his research of animal behavior and animal subjective worlds. The term 'Umwelt', in the sense of the subjective world of an organism, has been used by von Uexküll since 1909 (in his article of 1907 he still uses the term '*Milieu*', as different from '*Außenwelt*').

Von Uexküll has also emphasized that he is a follower of K. E. von Baer's (1792–1876) line in biology. He often cited von Baer's interpretation of biological time, and felt drawn also to his other views in general biology. Indeed, the Baltic German embryologist Karl Ernst von Baer developed an approach in biology, which has later been considered as, in a way, alternative and comparable in its importance to that of Darwinism (Gould [1977: 4], 'I insist on the rigid separation of von Baer and Haeckel'; Salthe [1993b: 247], 'Baer and not Darwin would become the central historical figure in theoretical biology').

It is well known that von Uexküll was not acquainted with the works of semioticians. Almost his only conversations with people close to semiotics were those in Hamburg with Ernst Cassirer (1874–1945) and Heinz Werner (1890–1964, the co-author of 'Symbol formation'; Werner 1919); however, they were both much younger, and von Uexküll's views were already established at that time. Later, he also corresponded to philologist Heinrich F. J. Junker (1889–1970). Probably far more important were the influences he got from the late romanticist atmosphere in Estonia, from the special biological environment in the Biological Station of Naples, and from the Heidelberg laboratory of Wilhelm Kühne (1837–1900, a pupil of J. Müller and the author of 'enzyme' notion).

Von Uexküll developed his approach in an extensive way in his book *Theoretische Biologie*, the second edition (1928) of which became well known and was later reprinted. Hermann Keyserling was among the early philosophers who proposed the whole epistemology to be based on von Uexküll's approach.

In the context of semiotics, it is of interest here to draw attention to one aspect of his methodology, namely, his very frequent use of musical metaphors. This practice was actually quite common among romanticist biologists. We also find it in the works of K. E. von Baer (1864). However, in the writings of von Uexküll, the metaphors like *Ton*, *Tastatur*, *Melodie*, *Motiv*, *Kontrapunkt*, *Komposition*, and others seem to play a particularly important role. Von Uexküll, when building his 'subjective biology' and at the same time criticizing Darwinians for not being scientific enough, needed a new methodology. Since he did not know semiotics or any other applicable terminology from the humanities, he used terms from music for this purpose.

> So sind die organischen Faktoren, die wir bei der Entwicklung bisher kennen gelernt haben: Gene, Plan und Protoplasma — Noten, Melodie und Klavier. Gene und Plan scheinen stets ganz tadellos zu sein, nur bei ihrer Einwirkung auf das Protoplasma können Störungen vorkommen, die wir experimentell ausnutzen; — wie eine Sonate Beethovens, die auf dem Papier tadellos ist, in ihrer Ausführung auf dem Klavier aber oft recht viel zu wünschen übrig lässt. (von Uexküll 1913: 175)

This aspect of von Uexküll's works deserves special analysis.

In areas which later have interested biosemioticians, several other trends can also be listed from this early period.

Charles Darwin (1872) wrote a book on the evolution of emotions, which was an early work on ethology, which was established as a branch and mainly developed in the twentieth century. In this context, a great impact on research in behavioral science in the nineteenth century was made by George John Romanes (1848–1894) (see Romanes 1883).

'Following Spencer, Romanes traced the objective manifestations of mind back to the most primitive forms of life, to plants and protozoa; indeed, he conceived mind as an organic development out of the phenomenon of life' (Richards 1989: 349).

As a reaction to important achievements in biochemistry and the spread of reductionism in biology, holistic views started to reappear in the last decades of the previous century. In an introduction to the textbook of physiological and pathological chemistry by Gustav Bunge (1887) (1844–1920, a scientist at Tartu University), neovitalism was introduced on to the scene (E. von Hartmann 1906). It is noticeable that the first monographs on theoretical biology, as well as the wider usage of the term 'theoretical biology' derived from biologists of clearly neovitalistic inclination (Reinke 1901). S. Meyen (1977) has shown in his article, 'The principle of sympathy', 'how Driesch had expressed all the basic dilemmas of biology' (Karpinskaya 1994: 114). H. Driesch's analysis of biological form is not very far from the interpretation of biological form in contemporary works on biosemiotics. When speaking about the positive sides of neovitalism, it is important to emphasize the basic assumption, that holistic concepts can be introduced in a fashion that does not violate the laws of quantum mechanics (Elsasser 1982: 21). An analogous assumption should hold when speaking about the positive features of several representatives of neo-Lamarkism (an approach which also has some features important for the history of biosemiotics): it should be assumed that Crick's central dogma holds. And indeed, at least several neo-Lamarckians (e.g., German botanist C. Nägeli and British paleontologist D. M. S. Watson) have clearly stated that acquired characteristics are not inheritable (cf. Bowler 1983; Cannon 1957; Mayr 1972), which means that the third mechanism of evolutionary perfection (an autogenetic one, or based on genetic predisposition) was considered possible besides those of natural selection or acquired adaptation.

The biologists adhering to the soft version of vitalism (or taking a compromise position between vitalism and mechanicism), according to E. Mayr, 'might be best referred to as organicists', since 'vitalism has become so disreputable a belief in the last fifty years that no biologist alive today would want to be classified as a vitalist' (Mayr 1988: 13). This should be considered in relation to the fact that von Uexküll's name is very often listed as the second one after Driesch in the articles about neovitalism in many encyclopedia. To the organicists in this sense, Mayr classifies among others also the above-mentioned J. Müller. Here, M. Delbrück's (1976) view can be reminded, showing a deep analogy between the Aristotle's form principle (usually held to be the beginning of vitalism) and the principle implied in DNA (cf. Mayr 1988: 13).

Among the early anti-Darwinian theories, developed at the end of the nineteenth century, one of the possibly more interesting ones for later biosemiotic views was the autogenetic theory of evolution (C. Nägeli, T. Eimer, etc.). Its main statement is the existence of an immanent (intrinsic) source of evolutionary change, the intrinsic trend towards the diversification of structure and behavior (cf. Csanyi and Kampis 1985). T. Eimer stressed the predictability of that trend, using the term orthogenesis (cf. Mayr 1988: 499). Several psycholamarckists (E. Cope, etc.) were also quite close to these views.

> It was their unshakable belief in teleology that induced Karl Ernst von Baer and other of Darwin's contemporaries to attack the theory of selection so temperamentally. Indeed, the belief in a teleological force in nature was so firmly anchored in the thinking of many that even among the evolutionists this belief had more followers in the first eighty years after 1859 than did Darwin's theory of selection. (Mayr 1988: 59)

After the works of August Weismann, it became generally accepted that acquired characteristics cannot be inherited. In modern terms, genetic memory works as read-only, as a ROM. As a result of this discovery, the autogenetic theories were thrown into the dustbin of history, together with all they included. The nomogenetic theory of evolution (L. Berg, A. Lyubischev, S. Meyen) has been one of the rare (and quite unknown to the majority of biologists) approaches which still held and developed in a way similar to the autogenetic view.

Memory is certainly an important component in semiotic processes. In this aspect, there exists a forgotten investigation from the theoretical biology of the beginning of the century — Richard Semon's (1859–1918) analysis of biological systems (1911), based on the notions of *mneme* and *engram* (which is related in its approach to the works of E. Hering (1912); E. Bleuler, E. Cope, E. Rignano, and S. Butler; cf. Blandino 1969). Bertrand Russell's book *The Analysis of Mind* was largely based on Semon's approach, through which the latter has also indirectly influenced contemporary philosophy. However, it is interesting to mention that in his later works Russell cited Semon's name hardly at all. The probable reason for this is hidden in Semon's belief in the inheritance of acquired characteristics, i.e., the view due to which its supporters lost their position on the map of science. But in the same way that this aspect of Darwin's views was considered insignificant in relation to his main views, so also in the case of Semon this assumption does not greatly influence his general ideas on biological memory.

The 1930s

Between the peaks of theoretical biology of 1900 and the 1960s–1970s, there was also a remarkable wave in the 1930s. It was characterized by the publication of the first influential monographs calling themselves 'theoretical biology' (L. von Bertalanffy, E. Bauer), Rashevsky's mathematical biophysics, A. Lotka's and V. A. Kostitzin's mathematical biology, and the start of several journals in this field. This has been called the golden age of theoretical ecology (Scudo and Ziegler 1978). As a result of works by R. A. Fisher, S. Wright and J. B. S. Haldane, the Darwinian theory of natural selection obtained its mathematical basis, and the so-called modern synthesis took place, giving rise to the synthetic theory of evolution. According to E. Mayr (1988: 550), 'An unexpected achievement of the synthesis was its effect on the prestige of evolutionary biology. The 1920s and 30s experienced an absolute low in the esteem of evolutionary biology within biology'. After that time, neo-Darwinism became the dominating view in biology for a considerably long time, and holism became unpopular. These developments did not give much to semiotic biology, at least during their first decades.

At the same time, holistic views in biology were still quite strong, but this can be seen as late inertia from the neo-vitalist or organicist period of the beginning of the century. Of the more mathematically biased holistic biologists, the works of D'Arcy W. Thompson (1917); J. H. Woodger (1930/1931, 1952); L. von Bertalanffy (1932), etc. should be mentioned.

Besides von Uexküll with his *Bedeutungslehre* (1940), there were also several other biologists influenced by neovitalistic approaches, in whose works some insights into semiotic biology can be found, among them Edgar Dacqué (1878–1945), Karl Friederichs (1878–1969), Friedrich Brock (1898–1958), Adolf Meyer-Abich (1893–1971), Richard Woltereck (1877–1944), and others.

E. Dacque's (1929) title *Leben als Symbol* for his book indicates that he perhaps had some semiotic ideas in mind. 'Es wird eine innere Verbindung zwischen den beiden Weltanschauungen des Rationalen und des Mythischen gesucht, und diese liegt in der Herausarbeitung des Symbolischen' (Dacqué 1929: iii). 'Das Individuum ist also, wie schon gezeigt, Symbol, in dem die Entelechie der Art begrenzten Ausdruck findet' (1929: 102). However, the book itself is not directly a semiotic one.

K. Friederichs (1937) analyzed the terms *Bedeutung*, *Sinn*, and *Wert* in his book on ecology. He also proposed the replacement of von Uexküll's term 'Umwelt' by *Eigenwelt*, which he saw as more appropriate.

A. Meyer-Abich (1963; Meyer 1934) has interpreted the work of von Uexküll as the first formulation of functional archetypes, in addition to the morphological archetypes already known in biology for a long time. According to a sectarian view of Meyer-Abich, physics should be a part of biology, not vice versa. However, this view can be seen in another light, if interpreted in the light of the ideas of Elsasser (1982) or Rosen (1991) on the need for broadening the basis of physics in order to include the nature of living processes.

F. Brock, who was a pupil of von Uexküll and his follower in the *Institut für Umweltforschung* in Hamburg, carried out some experimental research into animal Umwelts. He has also underlined the closeness of *Umweltlehre* to Leibniz's philosophy (Brock 1939; also Lassen 1939–1941).

R. Woltereck (1932, 1940), in his *Ontologie des Lebendigen*, has emphasized the existence of many intermediate forms between the 'somatisch-unbewusstes', and 'geistig-bewusstes Intendieren'. He has also analyzed the concept of adaptation from the point of view of subjective biology, and has stressed the role of representation for intentional phenomena. His approach might be considered as a development of von Uexküll's views. 'Für den lebenden Körper existiert nur, was ihn erregt, wofür er resonant ist, was für ihn Bedeutung besitzt' (Woltereck 1940: 431).

Thus, the influence of the organicist approach to the growth of semiotic trends in biology has probably been conspicuous; however, this has obtained a wider acceptance only due to the works of von Uexküll, the role and results of other scientists of this trend being left almost unnoticed. I do not claim with this that the works mentioned above are all valuable for contemporary semiotic biology, but I do claim that von Uexküll was not alone in his views.

In parallel, it should also be mentioned that in the works of several semioticians of that time (Ch. Morris, E. Cassirer), biology was already seen as occupying a space close to the science of signs.

Zoosemiotics: 1960s and after

As already noted, the 1960s precipitated the rise of a new powerful wave of theoretical biology, with the *Journal of Theoretical Biology*, biocybernetics, information theory, systems theory, Waddington, Rosen, many new journals and book series, etc. This was a period of applied mathematics in every field of biology, together with a diversification of theoretical approaches. Due to the great influence of biocybernetics in this period, communication processes received much attention by biologists.

This was also the start of extensive molecular biological research, with the deciphering and understanding of the genetic code and the principal ways of information transfer in a cell. There was also a rise in the application of information theory in biology and the quick development of mathematical biology, biophysics, and biocybernetics. At the same time, ethology became very popular.

Ecology, for which this period was also a time of large extension, is a branch of biology in which holistic views have had a strong influence, together with reductionist approaches, of course. E. P. Odum (1964) 'clearly delineated these two camps and placed himself in the forefront of the holists' (McIntosh 1988: 201). However, as A. Bramwell (1990) has so well illustrated, these relationships are very complex and any superficial division is not correct. According to Bramwell, the organicist biology of von Uexküll's time was that which gave the initial power to ecological views, extending far outside a professional biology.

The powerful introduction of cybernetic ideas and the concept of information into biology was thought to solve the eternal problems of the teleology of living together with the relationships of mind and matter. However, these problems instead resolved into many branches. Among them, an interesting book by Miller et al. (1960) should be mentioned: this applied the notion of plan to the explanation of animal behavior. Along the lines of this period, von Uexküll's approach could be intepreted as an early development of some biocybernetic notions. Also, several notions of H. Driesch were taken into use in the theory of self-regulating systems (for instance, equifinality, by L. von Bertalanffy, P. Weiss, etc.). There were, however, scientific branchings emerging from biocybernetics, represented by G. Bateson and H. Maturana, names often quoted in contemporary biosemiotic works.

S. Oyama, referring to Sommerhoff (1974), has stated that 'understanding of goal-directedness requires neither mentalistic language nor invocation of machine models, but conceptual clarity and investigation of actual relationships among variables and their consequences' (Oyama 1985: 133). Thus, despite the explanations given to goal-directedness in cybernetics (bearing in mind here the analogies between von Uexküll's functional circle and N. Wiener's feedback loop and its applications in neurobiology, e.g., P. K. Anochin), and K. Lagerspetz's (1959) and E. Mayr's analysis of biological teleology (proposing the term 'teleonomy' to make these biological phenomena acceptable to scientists of other philosophical backgrounds), it seems to be, nevertheless, appropriate to propose these terms for the next round of analysis — semiotic analysis (cf. Powell 1986).

This situation may have helped create an environment in which the semiotic approach could be applied in biology. It began as zoosemiotics, primarily through the works by T. A. Sebeok.

Sebeok's work has been immense, and it is largely due to him that biosemiotics, first of all, appeared in the 1960s, and second, is stepping towards its heyday today. Instead of listing his works I refer here to his bibliography (Deely 1995).

The belief in the at least potential possibility of conjoining semiotics with biology was also not alien to several other leading semioticians. In 1967, R. Jakobson said (1971: 675)

> The complete failure of mechanistic efforts to transplant biological (e.g., Darwinian or Mendelian) theories into the science of language or to fuse linguistic and racial criteria led linguists temporarily to distrust joint designs with biology, but at present, when both the study of language and the study of life have experienced continuous progress and stand before new, crucial problems and solutions, this scepticism must be overcome.

Along with Sebeok, there were several others who started to use semiotic terminology in ethology and biological communication studies. G. Tembrock (1971), influenced by zoosemiotics, applied the terms syntax, pragmatics, and semantics as basic aspects in his classification of communication phenomena in biology. The works of Smith, Kainz, etc. should also be mentioned (Sebeok 1989 [1979]).

Another branch of biology, besides ethology, which started to search for ways of integration with general linguistics, was molecular genetics. Marcel Florkin (1900–1979), a Belgian biochemist, published a long article on the biosemiotics of biochemistry, in which he applied the Saussurean approach to molecular processes of the cell (Florkin 1974; cf. Emmeche and Hoffmeyer 1991). In addition, Beadle and Beadle wrote:

> Science can now translate at least a few messages written in DNAese into the chemical language of blood and bone and nerves and muscle. One might also say that the deciphering of the DNA code has revealed our possession of a language much older than hieroglyphics, a language as old as life itself, a language that is the most living language of all. (Beadle and Beadle 1966: 207)

However, the majority of these attempts to apply semiotic terminology in biology (e.g., Tembrock, Florkin, Beadle) did not go very deep. This means one still probably cannot see in them the establishment of semiotic biology as an approach which considers the living process itself as having a basically semiotic nature. In this sense, particularly as concerns molecular biology, one may distinguish between the application of linguistic and semiotic approaches, the former being much more widely used in that period.

According to Robert Rosen (1991: 217), who has for a long time searched for non-reductionistic ways of building the theory of biology (as has another exact scientist in the field, W. Elsasser), 'biology is the way that we will find answers to most, if not all, of the deep questions which have engaged the human mind throughout our history. I have always believed that biology is the central science, in which all others converge, and which in turn illuminates them all with new light'. Not very far from these thoughts, in a series of conferences 'Towards a Theoretical Biology' in 1968–1972 with a small circle of foremost scientists, the paradigm for the theory of general biology was sought. According to the conclusion made by the organizer of these conferences, C. H. Waddington, this paradigm should come from general linguistics (Waddington 1972). This idea was developed in the papers of several participants: H. Pattee, B. Goodwin, R. Thom, E. C. Zeeman. My idea that this was not so distant from the route to biosemiotics (Kull 1993a) can be illustrated by a quote from Sebeok (1989 [1979]: 281):

Uexküll's scheme could, I think, productively be accommodated within Zeeman's developing model of the brain, thus making it amenable to mathematical exploration and generalization to cover any information with tolerance properties; in particular, this would allow for the combination of language structure with tolerance structure along lines worked out in some detail by Thom.

However, in the mutual integration of biology and linguistics, some new mathematical problems got more attention than its semiotic aspects, for instance, the generative grammars (Lindenmayer and Rozenberg 1976). Also, much research on the biological foundations of language (Lenneberg 1967; Lieberman 1984; Walker 1978) was quite far from semiotics.

The name 'biosemiotics' probably first appeared also in the 1960s. A book by Stepanov (1971) includes a chapter, 'Biosemiotics', in which he described the views of J. von Uexküll, and which is often considered as the first usage of the term. However, Bülow and Schindler (1993: 72) notice that the term 'biosemiotics' was already used in 1961 by Friedrich S. Rothschild (b. 1899) in the conference 'The Psychology of the Self' in New York. According to Rothschild (1989: 194),

Hier nannte ich zum ersten Mal die symboltheoretische Methode der Untersuchung der psychophysischen Relation Biosemiotik. ... Dieser zweifache Aspekt von Zeichen, einmal Strukturen zu bilden, die man in ihren physikalischen Eigenschaften erforschen kann, und ausserdem geistigen oder seelischen Intentionen als Ausdruck zu dienen, gilt für alle organismischen Strukturen. Überall, von Gehirn bis zu den einzelnen Zellen des Leibes, konnte die

Biosemiotik die Organisation von Kommunikationssystemen nachweisen, die sinnvolle Informationen und sinnvolle Intentionen vermitteln.

Despite the first introductions to the field of biosemiotics published in this period, of wide knowledge about zoosemiotics and an interest in animal languages, and seemingly important preliminary works towards the integration of linguistics and biology, it seems that there were still very few people who really believed that biosemiotics was a deep, true fundament for future biology. Sebeok (1968, cited in Deely 1990: 85–86) was the one who said: 'A mutual appreciation of genetics, animal communication studies, and linguistics may lead to a full understanding of the dynamics of semiosis, and this may, in the last analysis, turn out to be no less than the definition of life'. However, it soon happened that many people started to accept this view.

Last decades: 1980s and 1990s

The decades after the great peak in the 1960s and 1970s marked a clear decline in general interest in theoretical biology. Biosemiotics, simultaneously, is growing remarkably. But let me first note some trends appearing in neo-Darwinian biology, emphasizing the communicative aspects.

'In the past two decades the importance of sexual selection has again been acknowledged; ... this topic has become one of the major concerns of sociobiology' (Mayr 1988: 505). This means a growing interest in the role of certain aspects of communication by evolutionary biology. Along with the works of E. O. Wilson, W. D. Hamilton, D. Zahavi, and others, the concept of memes (R. Dawkins) has achieved a wide distribution in biologists' writings. J. Maynard Smith developed a game theoretic model to describe the evolution of communication. J. Maynard Smith and E. Szathmary (1997) have written about the biological background of language origins. G. Edelman (1992: 74) proposes to develop 'sciences of recognition, sciences that study recognition systems', including evolutionary biology, immunology, and neurobiology. From philosophy (but following the same biological tradition), D. Dennett has made strong attempts to explain the intentional aspects of living systems.

The linguistics and step-by-step semiotics of molecular texts have been more and more analyzed in molecular biology (e.g., Brendel 1986). 'I shall guess, the history of linguistics will be repeated in the development of molecular biology' (Berlinski 1978: 180). According to R. Pollack (1994: 151), 'molecular biology now confronts a new and unpredicted uncertainty, a boundary on our ability to know the final meaning of the genes we study'. 'The trend is clear: we can expect to find more and more examples of the richness of a real language in our cells. DNA and protein have grammar and syntax, and we have already come upon typographical errors, double meanings, synonyms, and other subtleties' (1994: 153).

The revival of von Uexküll by Sebeok was quite sudden. In his 'selected and annotated guide to the literature of zoosemiotics and its background' (Sebeok 1969), von Uexküll's name is still lacking. Despite some occasional references earlier (cf. Sebeok 1989 [1979]: 193), the breakthrough was made in Sebeok's talk at the 'III Wiener Symposium über Semiotik' in 1977 (Sebeok 1989 [1979]: 187). Through Sebeok, this had a positive feedback effect on ethology and many other areas, which started to refer to von Uexküll again.

Shortly after the revival of von Uexküll by Sebeok, T. von Uexküll published a compendium of his father's works, supplied with extensive commentaries (J. von Uexküll 1980). This was followed by publication of translations of *Bedeutungslehre* and *Streifzüge*... in *Semiotica* (J. von Uexküll 1982, 1992), and the inclusion of von Uexküll in *Classics of Semiotics* (Krampen et al. 1987).

Von Uexküll did not write much about plants (except his well-known example of oak and rain, which does not seem a good choice for him to have made, from the point of view of a professional plant ecophysiologist). To fill this gap, M. Krampen (1981) wrote an article from which the field called phytosemiotics is considered to begin (unfortunately, he again paid too much attention to that particular example). J. Deely (ed. 1986, 1990) responded with criticism, and introduced the notion of physiosemiosis, to include the cosmic evolution in general.

G. Bentele's book (1984) was one of the first which introduced evolutionary perspectives into the establishing field of biosemiotics. A programmatic paper for biosemiotics, in which a series of statements on the semiotic aspects of biological evolution is formulated, is the collective article by M. Anderson et al. (1984); e.g., they stress the importance of coevolution and symbiosis. Also, 'communication begins with a decoder, not with the encoder, whether "intentional" or not. This insight is particularly crucial to the understanding of evolution as a part of semiosis'.

A major new aspect appeared through the discoveries made in immunology, which showed that there exists another system capable of learning and filling the whole animal body besides the nervous system. After the works of N. Jerne, which pointed out some linguistic features of the system, a remarkable book on immunosemiotics was published

(Sercarz et al. 1988). Shortly after that, the semiotic interpretations of the processes taking place inside an organism were integrated in a large paper on endosemiotics (T. von Uexküll et al. 1993).

Also Thure von Uexküll's (1979, 1982, 1986) credit is the building of a bridge between biosemiotics and psychosomatic medicine, with which he had begun much earlier.

The book *Biosemiotics* edited by T. A. Sebeok and J. Umiker-Sebeok (1992), with its 27 authors, was probably the first book with 'biosemiotics' in the main title, and, though quite diverse, is still the largest volume in this field.

The article by J. Hoffmeyer and C. Emmeche (1991) on code duality seems to herald a new quality in the works on biosemiotic ontology, since it introduces a formulation of biological information which is applicable to all levels of living systems, and which is the guiding thread of all the following writings by Hoffmeyer in his characterization of 'semiosic body-mind'.

Semiotics has been seen as a tool for approaching the epistemologic problems of biology. This has several dimensions. Firstly, biosemiotics seems to propose for biology a sort of philosophical basis or background, in the hope of replacing the one which has been applied at least since Ernst Haeckel, namely, 'Evolutionstheorie als Weltanschauung' (cf. J. von Uexküll 1907; Weingarten 1993). Secondly, it enables the introduction of subjectness, i.e., organism as a subject, into the biological realm (cf. J. von Uexküll 1931b; Woltereck 1932). And thirdly, it helps to understand the development of mental features through the semiotically interpreted evolutionary epistemology (Schult 1989; Hoffmeyer 1996b). (Since there is a difference between genetic and evolutionary epistemology, the proper aspect here may be genetic epistemology; cf. Kesselring 1994.) Hoffmeyer has emphasized the importance of biosemiotics as an approach which can resolve the dualism:

> To modern science, dualism still holds good as a way of dividing the world into two kingdoms, those of mind and matter, the cultural and the natural spheres. ... And it is this boundary that biosemiotics seeks to cross in hopes of establishing a link between the two alienated sides of our existence — to give humanity its place in nature. (Hoffmeyer 1996a: 94)

According to the biosemiotic view, 'system could be *more or less rational*; rationality is something that can occur at levels other than that of the human psyche' (1996a: 93).

Within the last decades, there has also been much particular work done on developing the semiotic understanding of different biological phenomena.

E. Baer (1984: 6) said, 'we must look at adaptation as a semiotic phenomenon, that is, as a process of signification'. This is an important point, since the notion of adaptation certainly requires reinterpretation. The existing notion of adaptation in biology, which is either connected to fitness and thus disconnected from form, or, when described as a form then loses its testability, needs a new theoretical foundation. The drawbacks of the contemporary approach were described by Gould and Lewontin (1979).

An interesting case in which semiotic aspects appear is mate recognition and, together with this, the mechanism which is responsible for the origin and holding of biological species as discrete units (Schult 1989, 1992; Kull 1992, 1993b). This is closely related to the recognition concept of species as developed by H. Paterson (1993). The role of genetic communication between bacteria was investigated by S. Sonea (1992) in a similar context. Another semiotically interesting phenomenon, in which discreteness also arises, is categorical perception (Stjernfelt 1992). These are examples of more general reciprocal mechanisms, which are responsible for a large set of spatial, temporal, and morphological discreteness in various biological systems, at the same time being a prerequisite of any linguistic phenomena.

B. van Heusden, when speaking about biosemiotics, has tried to formulate the specificity of human perception. 'Humans are aware of the fact that they do not actually perceive forms ..., but that they perceive *with* forms, that ... the world presents itself to us as different from a remembered past' (van Heusden 1994: 68). Thure von Uexküll has stressed that the difference lies in the temporal aspect, namely, that there appears a time lag between the perception and reaction in the case of humans. Indeed, the more biology is integrated into semiotics, the more important it will be to reformulate the sources of the clear difference between bio- and anthroposemiosis.

Kawade (1996), in his recent article, has renewed the semiotic interpretation of biomolecular processes. Ray Paton (1997) has analyzed in what sense a biological form can be a text, or an enzyme can be a verb (on the organism as a text cf. Sebeok 1977; Löfgren 1981; Kull 1997).

There are also attempts to make the information concept more appropriate for biology with the help of semiotics (Sharov 1992). 'With semiotics the observer could be brought right into the models. Furthermore, this now allows the *meaning* of information to be modeled as well as the information itself, as is done in information theory. Indeed, as I conceive it now, information theory must become embedded in semiotics' (Salthe 1993a, xi; cf. Hoffmeyer and Emmeche 1991). Brier (1995) has analyzed the problems of the integration of biosemiotics and cybernetics.

Recently the term 'ecosemiotics' was introduced by W. Nöth (1996), followed by a series of responses in a special issue of *Zeitschrift für Semiotik*. However, the semiotic approach to ecology was introduced earlier, e.g., by A. Levich (1983), whose particular interest concerned the applicability of Zipf's law in the ecological communities.

Hoffmeyer's book (1996a) deserves particular attention. He is more clear and more radical than previous authors, claiming that biosemiotics is an approach which can give the solution to the main problems of mind-body dualism and relationships of humans and nature. A collective review of this book was published in *Semiotica*.[2] However, there are many issues in the philosophy of biology about which Hoffmeyer does not say a word. In the extremely complex and intertwined sphere of biological theories, silence can sometimes be the best answer, particularly in the formation phase of its views. When the development proceeds, however, more will become expressed and interpreted. And semiotics, among others, is hopefully teaching us to behave in an otherwise too complex mixture of meanings in the theoretical spheres of biology.

Thus, to conclude the description of this last chapter, which began with Sebeok's revival of von Uexküll, one can characterize it as a rapid growth of biosemiotics in this period. In addition to the publication of von Uexküll's translations into English, many new authors came into the field, special issues of journals appeared (*Zeitschrift für Semiotik* 8 [3], 1986, 15 [1-2], 1993, 18 [1], 1996), a series of books was published within a short time (Sebeok and Umiker-Sebeok 1992; Salthe 1993a; Witzany 1993; Pollack 1994; Yčas 1994; Hoffmeyer 1996a), and many books on semiotics paid much attention to biosemiotics (Deely et al. 1986; Deely 1990; Nöth 1990, 1994; Sebeok 1990, 1994; Posner et al. 1997; Merrell 1996; etc.).

Meetings

In addition to published works, epistolary and oral discourse, no doubt, also play a role in scientific development. In this context, at least, Thomas A. Sebeok's contribution has to be mentioned.

In a short time, a number of symposia, workshops, and conferences in biosemiotics have been organized, almost all taking place within the last decade. It is worth mentioning the workshop 'The Semiotics of Cellular Communication in the Immune System' in 1986 in Italy (Sercarz et al. 1988) with a contribution by U. Eco (1988). Probably of particular importance were the small workshops in Glottertal (Germany) which took place in 1990 and 1992, in which an attempt was made to establish an International Biosemiotics Society (cf. Sebeok 1991: 7). Also, a meeting

'Biosemiotics and Biotechnology' in 1991 in Denmark should be mentioned. After that, symposia on biosemiotics were held at international congresses of semiotics in Berkeley (USA), 1994, and in Guadelajara (Mexico), 1997. The meetings of the International Society for the History, Philosophy, and Social Studies of Biology held in Leuven (Belgium), 1995, and in Seattle (USA), 1997, also included biosemiotic sections. An important event was the conference in Toronto, called 'Semiosis. Evolution. Energy', in 1997. The congress 'Symbiogenesis and Carcinogenesis' in Freiburg, Germany (1998) was probably the first meeting in experimental biology which included a session on biosemiotics (*Endocytobiology and Cell Research* 13, supplement).

In Denmark, a series of smaller biosemiotic meetings was held, mainly due to the activities of J. Hoffmeyer, C. Emmeche, S. E. Larsen, etc. Since the end of 1980s, the biosemiotic group was formed at the Institute of Molecular Biology of the University of Copenhagen, and there is the Danish Society for the Semiotics of Nature.

Concerning the relationships with theoretical biology, it is interesting to mention three regular seminars on theoretical biology, which arose independently in St. Petersburg (led by S. Chebanov), in Moscow (A. Sharov, A. Levich), and in Tartu (K. Kull, T. Tiivel) in the 1970s. Having a nomogenetic bias, all of these figures later made a shift towards biosemiotics. Together they organized the conference 'Biology and Linguistics' in Tartu in February 1978, which was probably one of the first large biosemiotic meetings on a world scale. In October 1988, a small workshop, 'Semiotic Approach in Theoretical Biology' was held at Laelatu Biological Station (Estonia). From 1988 to 1990, A. Sharov organized a series of seminars and 'Winter Schools on Biosemiotics' at Moscow University. S. Chebanov established similar activities at the University of St. Petersburg. In 1998, N. A. Zarenkov gave a lecture course 'Semiotic-linguistic Theory of Biology' at Moscow University.

In Estonia, about which I know more, a great deal is also going on. An issue of the periodical *Vita aeterna* (no. 5, 1990) of the students' Theoretical Biology Group of Tartu University was devoted to biosemiotics. Since 1993, several guest scientists (T. von Uexküll, J. Hoffmeyer, S. Chebanov, B. van Heusden, T. A. Sebeok) have lectured on biosemiotics in Tartu University. In 1993, the Jakob von Uexküll Center was established in Tartu. Recent Estonian Spring Schools in Theoretical Biology were entitled 'Theory of Recognition' (1995) and 'Languages of Life' (1996). A regular lecture course on biosemiotics was introduced by K. Kull at Tartu University in 1993, in the year of the death of Yuri Lotman, but still with his introductory words, dictated in hospital. Now, this course is read every year and is included in the standard semiotics curriculum. Also, a biosemiotic course was read by A. Turovski at Tallinn University of Educational Sciences in 1997.

Post-Darwinism

The majority of biosemioticians have been quite critical towards neo-Darwinism (e.g., Salthe 1993a; Witzany 1993). Indeed, post-Darwinism as it has developed in recent decades seems to correspond and fit much better with the needs of semiotic biology. Hoffmeyer (1996a: 58) wrote: 'We need a theory of organisms as subjects to set alongside the principle of natural selection, and Jakob von Uexküll's *umwelt* theory is just such a theory. Ironically, however, it is only through integration with the theory of evolution that the *umwelt* theory can truly bear fruit'.

Except for some cases when this was used to denote the whole period after Darwin's death, the term *post-Darwinism* as signifying the overcoming of the neo-Darwinian period was first used not later than 1986, at a meeting in Osaka on structuralism in biology (Ho 1989). That meeting, which declared itself in clear opposition to the 'mainstream' theoretical biology, also noted its historical continuity with a 'marginal' tradition in theoretical biology, coming from Joseph Needham, J. H. Woodger, and other members of the Cambridge Club of Theoretical Biology (Goodwin et al. 1989: vii; Abir-Am 1987). On the other hand, it is very noticeable that the nomogenetic approach in Russian biology, represented by L. Berg, A. A. Lyubischev, S. Meyen and others, which has brought its tradition back to K. E. von Baer with his criticisms of Darwinism, resembles in many aspects the above-mentioned structuralistic biology (Schreider 1977; Brauckmann and Kull 1997). Meyen, in his later works, considered it possible to reach a theory (a new synthesis) into which these particular views on evolution can be included.

The main emphasis of the post-Darwinian explanation of evolution is concerned with the role of the form and activity of organism. The neo-Darwinian mechanism of natural selection appears to represent a special case in the post-Darwinian picture of evolution.

In this context, it is interesting to note some recent trends in evolutionary biology, which emphasize the role of an organism's activity. One of these is the resurgence of interest in Baldwin's effect (Baldwin 1896; e.g., Belew and Mitchell 1996). The other is represented by works which consider epigenetic changes (through the mechanisms of epigenetic inheritance) to be primary factors in evolutionary change (Jablonka 1994). There are also other works emphasizing organisms as subjects of evolution (Weingarten 1993; Kull 1993b).

Due to the results of molecular biological research and the modeling of complex systems, it is evident that the material structure of living systems is now understood in remarkable detail. In other words, the molecular mechanism of life is more or less solved. However, as a matter of fact, biologists still cannot precisely define or delimit what to call the living process. This seems to be a point at which, intuitively, semiotics may be of assistance. However, if some set of molecular processes of a cell will be identified as semiosis, i.e., truly semiotic, describable fully, including all its components, in exact molecular terms, then why should not this situation mean that semiosis can be modeled mathematically? This would create a new situation for semiotics itself, since no semiosis has been fully described before (in the sense of an external 'objective' point of view, the view from 'nowhere' of natural science), due to the participation of conscious mind in all cases. However, even in the case of cellular semiosis, the system is not simple at all. A possible scenario of this says that the mathematical models, except maybe the ones for the most primitive semiotic systems, are of such a level of complication, and in principle not reducible to more simple ones enabling comprehension without losing their identity with semiosis, that the only way to describe these systems is to apply the natural language, as has traditionally been done in semiotics.

This aspect has hardly been discussed in biosemiotics (with the exception, for instance, of the avoidance of mathematics by von Uexküll, Hoffmeyer, etc.). However, this may be important in order to achieve the acceptance of the semiotic view by biologists who are used to the natural scientific approach.

There exists an additional reason to believe this scenario. Namely, natural language presumes and includes the process of categorization. Categorization discerns natural languages from formal ones — the latter use logic to define and delimit their terms, whereas in natural languages the categorization which delimits the signs is a pre-linguistic process, analogous to speciation, or category-formation in perception. The categories as wholes with diffuse boundaries, although separated from the neighboring categories by hiatuses, are objects upon which natural languages are based, and for the description of which they are well suited. This is similar to the way in which we can quite easily describe biological species using natural languages, the mathematical and formal definition of which causes many problems. 'Privileged sameness relations cannot be found for the demarcation of the species' (Dupré 1981: 83). This is the same as if we tried to turn the scientific analysis of tokens or words, particularly that which concerns their meanings, into a mathematical theory. No doubt, the linguists who do it via their mother tongue can do it no worse.

Conclusion

In conclusion, it seems to be noticeable that there has been a considerable difference between the holistic and reductionistic — or Baerian and Darwinian — schools of thought in biology in the successfulness of their attempts to conjoin signs and life, or semiotics and biology. Many of the semiotic biologists (von Uexküll, Salthe, Hoffmeyer, Chebanov) can be identified as belonging to the holistic, or Baerian, biology (I do not mention here biologic semioticians, who should probably be viewed primarily in the context of the trends in semiotics and not so much in those of biology). An explanation of the scarcity of semiotic biology in this century thus stems from the fact that Baerian biology has been in a suppressed minority position almost throughout the century, except perhaps for the first and last decades (i.e., in the periods of neovitalism or organicism and post-Darwinism), when its supporters were slightly better known or noticed. However, the dialogue between these two lines of thinking in biology has never stopped and has continuously enriched both views. The rapid growth of biosemiotics in the last decade can be seen as a parallel to the rise of post-Darwinism in evolutionary biology, which is also a result of that dialogue. What is needed, and what it may hopefully bring, is both the broadening and deepening of the views. This would include the better understanding and skillful interpretation of deep but forgotten investigations, grasping more from scientists of other views. However, this requires less politics (defined here as following more social requirements than the logic of a topic) in science. This would probably be too much to hope.

Many examples of semiotic interpretation of biological phenomena have already been collected, and there is a set of ideas about the generalizations and paths to pursue. Their review would grow into a volume or more. However, what is still seemingly absent is a methodical explanation for ordinary biologists on how to apply semiotic analysis to the systems which they know.

The next stage in the development of biosemiotics (in analogy to the developmental logic of other branches of sciences), which may probably be reached soon, is the stage of larger reviews which try to list and integrate the whole field. And of course, there should appear open criticism of the whole approach from various sides — which has until now been quite exceptional and tentative.

We may already notice, I believe, some signs of the beginning of the *third* wave in theoretical biology (after its start at the turn of the century, its first wave in the 1920s and 30s, and the second wave in the 1960s and 1970s), with a possible keyword *meaning*. It may mean the synthesis of theoretical biology and biosemiotics, biology and semiotics. Or it may not.

Notes

1. I thank Sabine Brauckmann, Jesper Hoffmeyer, Thomas A. Sebeok, and Thure von Uexküll for supplying me with valuable information which has improved this article.
2. *Semiotics in the Biosphere: Reviews and a Rejoinder*, published in 1998 as a special issue of *Semiotica* (120-3/4: 231–482).

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