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Bohr's Complementarity Framework in Biosemiotics

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Abstract This paper analyses Bohr's complementarity framework and applies it to biosemiotic studies by illustrating its application to three existing models of living systems: mechanistic (molecular) biology, Barbieri's version of biosemiotics in terms of his code biology and Markoš's phenomenological version of hermeneutic biosemiotics. The contribution summarizes both Bohr's philosophy of science crowned by his idea of complementarity and his conception of the phenomenon of the living. Bohr's approach to the biological questions evolved – among other things – from the consequences of an epistemological lesson of quantum theory and in light of complementarity of observer as a priori living creature and *ex post* scientific explanation of the living. In a manifestation of the phenomenon of the living, each model of living system and its description makes accessible – from its own presuppositions, contexts and concepts – some features which are not accessible from the others. Nevertheless, for a general understanding of that phenomenon, incompatible sophisticated approaches are equally necessary. Bohr's epistemology of complementarity turns out to be a heuristic and methodical framework for testing the extent to which biosemiotics can become one of the special sciences or its potential as a cross-disciplinary branch of study.

Keywords Bohr · Complementarity · Barbieri · biosemiotics · Markoš · Hermeneutic biosemiotics

Introduction

The well-known development of mechanics, dynamics and mathematics within the Galilean total mathematisation of nature had a huge impact on life sciences, which adapted in a step by step fashion to the Galilean and Newtonian demands on scientific explanation, methods and research programs that had already successfully been applied to astronomy and physics.

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This process was further supported by rapid progress in molecular biology since the discovery of DNA structure in the 1950s. There grew up "a metaphysical thesis" which asserts that "all facts, including the biological facts, are fixed by the physical and chemical facts; there are no nonphysical events, states, or processes, and so biological events, states, and processes are "nothing but" physical ones" (Rosenberg 2008: 120).

Molecular and cellular biology consider life to be a complicated molecular process regulated by genetic information. As a well-known textbook explains, "it is to *cell biology* that we must look for an answer to the question of what life is and how it works" and it is, in fact, chemical reactions which enable life or "processes that allow us to move, think, talk, and experience the world around us" (Alberts et al. 2004, 1 and preface V). Simply put, cells mechanically transcribe their genetic information from DNA to RNA / mRNA and thereafter ribosomes mechanically translate the genetic information from mRNA into primary structure of proteins according to the genetic code. From proteins and their products our body is finally composed by this mechanical process (Alberts et al. 2004: chap. 7). Despite its epochal insight for understanding life, that bold generalization about life is still hugely problematic. The description of life is here limited to the exclusivity of mechanically established genetic code, regarded as a non-cultural "frozen accident" (Barbieri 2003: 2), which has been the sole organic code on a molecular level for almost four billion years. There are then no other organic codes and there is no place for other immanent and highly complicated performances of the living which are not simply objectivisable by means of special sciences or humanities (Markoš 2006).

This article aims to propose a new epistemological framework with which to comprehensively answer the question of *what life is and how it works* using Bohr's original idea of complementarity. His notion offers a way to approach incompatible and mutually non-inferable descriptions of an examined phenomenon and is applicable not only to quantum theory but also to other sciences including biosemiotic studies. Epistemology of complementarity will firstly be illustrated by Bohr's own approach to the phenomenon of the living and then applied to the three existing descriptions of living systems: mechanistic biology, represented by molecular or cell biology; Barbieri's version of biosemiotics within his code biology; and Markoš's version of hermeneutic biosemiotics influenced by Heidegger's non-objectivistic hermeneutic phenomenology.

Generally speaking, Bohr's approach, and the approach of later biosemioticians, including Barbieri and Markoš, call for a more complex understanding of the phenomenon of the living. This should enable us to work not only with chemical-physical regularities and specific mechanistic terminology, but also with common notions like memory, experience, meaning, meaningfulness or functions that are characteristic of the life phenomena (see below). Since these substantive features are not mere epiphenomena within the evolutionary mechanism of natural selection, Bohr and a majority of biosemioticians try to incorporate the fact that we also are from the beginning an essential constituent of the evolutionary history of the living and any objective description of the living systems has also evolved as a part of that immense dynamic process (Grygar 2014; Sebeok 2001; Favareau 2010; Kull et al. 2011; Markoš 2002 2015a, b).

Bohr defined himself more or less in opposition to the epistemology of modern science and purely mechanistic or objectivistic attempts to unify explanation and understanding of organic or inorganic nature. According to him, despite persistent scientific efforts to eliminate any inconsistency both from everyday life and in scientific descriptions, we encounter phenomena which cannot be fully, causally and unambiguously explained on the basis of classical or modern presumptions – and this holds especially for biological inquiry. He realized that biology has a special position among sciences. It is a natural science which on the one hand – following the ideals of chemistry and physics – explores the life or organisms as any other measurable object of inanimate nature and, on the other hand, tries to objectively describe life in its livingness or capabilities in a situation where we, as observers, are uniquely and inseparably connected with the living we examine (Grygar 2014).

Biosemiotics realizes these problems and discusses how biological approaches could incorporate and work with such notions as, for instance, *meaning*, *sign* or *interpretation* derived from the humanities or subjective-relative contexts of everyday life. Moreover there are semiotic and hermeneutic processes that happen at any level of the living from a cell to the ecosystem (Sebeok 2001; Hoffmeyer 2007; Kull 2011) and these processes are "what distinguishes all that is animate from the lifeless" (Sebeok 1986: 15). In molecular biology, concepts like *code*, *information*, *transcription*, *translation* and the metaphor of the *book of life* written in DNA have been widely used. It seems, nevertheless, that these concepts suddenly lose their original sense when applied to biology, and the imminent question is then how to keep essential features and contexts of the living systems by means of the scientific notions, descriptions or experimental research. While biosemiotics, in answering this question, has become established as a branch of study trying to bridge and embrace different disciplines (and their results), from biology, brain and behavioural sciences to semiotics, linguistics and philosophy, a solution to such problems can be provided or improved via Bohr's complementarity.

Bohr's understanding of complementarity and his approach to the phenomenon of the living are apparently unfamiliar both to readers of biosemiotics and the majority of the scientific community. The idiom "complementarity" is a common word (coming from Latin) that is used everywhere including biosemiotics but mostly in a non-systematic or non-Bohrian way. In volumes of biosemiotics (available to me), complementarity is mostly employed after the fashion of complementing strands of DNA, supplementing something that is variously different or dualistic etc. (cf. Barbieri 2007, 2008b; Hoffmeyer 2008; Favareau 2010; Kull et al. 2011). Complementarity is in rare cases used in Bohr's sense of incompatibility and irreducibility. Pattee, for example, speaks about complementarity in biology or biosemiotics between "the concept of information in biology" and "the concept of physical structures and laws" (Pattee 1979: 218), between symbol / genotype and matter / phenotype (Pattee 1978, 2008), or in specific contexts between "the subject and object, the knower and the known, the mind and the brain" (Pattee 2001: 343). As Pattee uses it, the essence of "complementarity is not in the recognition of this subject-object distinction, which is common to almost all epistemologies, but in the apparently paradoxical articulation of the two modes of knowing" (Pattee 1978: 192). More recently Artmann has described complementarity between "the "hard" physico-chemical objectification of living systems" and "a meta-scientific position by "soft" biosemiotic descriptions of organisms as subjective agents making sense of their environments" (Artmann 2007: 216). Kull elaborates on complementarity between the *physical eye*, physical reality or objects and the *semiotic eye*, semiotic reality or objects (Kull 2011). Pattee and Artmann explicitly drew from Bohr's original writings, however, they, as many scientists and Bohr's collaborators or interpreters, misleadingly refer to the "principle of complementarity". Bohr purposely and advisedly never connected complementarity with any principle, because for him complementarity is a new epistemological way of thinking which intersects varied scientific specialisations (Folse 1985; Grygar 2014).

This contribution follows and elaborates on Pattees's, Artmann's and Kull's notions and the suggestions of Delbrück and Wheeler, who were immensely influenced by Bohr's thinking. Delbrück indicated that biology or science generally "would achieve a deep understanding of its objects only if it arrived at a complementary description" (Fischer 2007: 676) and Wheeler declared that "complementarity is the most revolutionary scientific concept of this century" (Wheeler 1963: 30; he uses the word "principle"). The leitmotif of the study is to clear up Bohr's original conception and present it as an inspiring, heuristic and methodical framework for biosemiotic thinking and cross-disciplinary research.

Concerning Bohr's philosophy of science, I will draw on my earlier book, so as to avoid overloading the paper with numerous references to literature (Grygar 2014). I want to remark that Bohr's thinking has a number of features in common with Husserl's intentional phenomenology and Heidegger's hermeneutic phenomenology. Regarding Markoš's hermeneutic biosemiotics, it is evident that he draws among other things on Heidegger's hermeneutic phenomenology or conception of the pre-predicative and predicative structure of language and understanding. Although such analyses are not the aim of this paper, in what follows I will mention phenomenology especially in cases which complement Bohr's or Markoš's approach to the phenomenon of the living.

Bohr's Epistemological Lesson of Quantum Theory and Complementarity

Though Bohr did not engage in any special kind of philosophy, he emphasised a *philosophical*, *epistemological* or *general lesson* (repeated in: Bohr 1972–2008, CW10[1]) that quantum theory teaches us in relation to the very conditions of observing and describing nature. This is closely associated with his critique (analogous to biosemiotics) of the Cartesian tradition (psycho-physical parallelism) or modern science based on strict subject-object partition and physical causality. Bohr attempted to create a suitable conceptual framework not only for a new understanding of the emerging and, at that time, disputed quantum theory, but also for cross-disciplinary research. He tried to solve this issue via the idea of complementarity, which is entwined with his notion of language and phenomenon.

Here it is important to warn against common misconception notions about complementarity. In short: the idea of complementarity should not be confused with any scientific principle (like e.g. Werner Heisenberg's uncertainty principle), it is not simply replaceable by the notion of duality (like e.g. wave-particle duality), it cannot be considered some sort of derivative of the uncertainty principle, and complementarity is not interchangeable with the so-called Copenhagen interpretation.[2] Moreover Bohr's

[1] In the following I will build on Bohr, N. (1972–2008). *Collected Works, volume 1–13*. I will refer to it as e.g. (Bohr 1972–2008 (CW6): 164).

[2] Heisenberg, who worked closely with Bohr, assumed that there was no substantial difference between his and Bohr's version of quantum theory. Nevertheless, there are important distinctions. Bohr did not interpret Heisenberg's uncertainty principle (relations), originated in spring 1927, the same way Heisenberg did, nor did he need to operate with the so-called collapse of the wave function (reduction of the wave packet), which Heisenberg established as the standard constituent of the Copenhagen interpretation in 1929. As regards the Copenhagen interpretation, which reputedly originated in September 1927 at a well-known conference in Como via Bohr's so-called Como Lecture, Heisenberg apparently did not introduce the term "Copenhagen interpretation" until the 1950s, and there are still no precise specifications of this interpretation. Furthermore, in comparison with Heisenberg, Wigner and others, Bohr did not put an excessive emphasis on the observer or consciousness in the processes of measurement (e.g. Camilleri 2009; Folse 1985; Grygar 2014; Heelan 1965, 2016; Heisenberg 1949; Wigner 1961).

way of thinking was essentially complementary even before his famous Como Lecture in 1927, but without the explicit use of the word "complementarity".[3]

We can define Bohr's idea (the viewpoint, argument, concept) of complementarity as a new epistemological framework for thinking across various fields of study; the framework, which could serve both quantum theory and as a heuristic and methodical approach to any kind of scientific research. Generally speaking, some phenomenon (a subject of study) may be comprehensively described by means of two mutually exclusive languages (ideas, concepts, models, results of two experimental arrangements) *La* and *Lb*. Although one aspect of the given phenomenon may be understood by means of *La* and another by means of *Lb*, there is no aspect of this phenomenon which would be describable simultaneously by means of *La* and *Lb*. Likewise the examined phenomenon does not correspond only to *La* or only to *Lb*, and *La* is not transferrable or derivable from *Lb* (or vice versa). Only within this complementary frame do certain paradoxes, principles, specific interpretations, dualities and incompatible pictures of nature gain their overall meaning (Grygar 2014; cf. Pattee 1978: 191; 2001: 343). As a visual demonstration we can use, for example, the picture of the well-known Rubin's vase.[4] At one moment, in the picture, we can see sharply and distinctly either a vase (*La*) or two profiles of a human head (*Lb*). We cannot derive the vase from the profiles; there is no causal connection to the vase, and vice versa. But for a complex understanding of the subject of study (*Lab*), i.e. for a complete perception of the picture, we must take into account both exclusive ways of perceiving it. To express, for example, complementarity between physical and semiotic realities or physical and semiotic descriptions Kull uses Sandro Del Prete's well-known picture of Message d′ Amour des Dauphins (Kull 2011: 117–120).

We should further distinguish between A) non-sharp complementarity as a notion of mere complementing of contradictions or differences which are from the beginning somehow mutually dependent like *life* and *death*; *yin* and *yang*; *mind* and *body*; *momentum* and *position*; *intentional act* and *intentional object*; couples like *teacher* and *pupil*; coupling of DNA chain's bases etc., and B) sharp complementarity as a meaningful complementing of elements, which are originally exclusive, mutually and

[3] Regarding the use of the word "complementarity", Bohr introduced this word in his manuscript (draft) in the summer of 1926, however according to editors Bohr was mistaken (because of the content of the physical subject) and there should have been written 1927 (Bohr 1972–2008 (CW 6): 27 and 58). By contrast Petruccioli writes that editors were rash and Bohr's draft is really from the summer 1926 (Petruccioli 2011). At any rate, we can trace Bohr's complementary thinking even back to his youth. Young Bohr was hugely influenced by cross-disciplinary discussions, organized by his father, the experimental physiologist Christian Bohr, who hosted them in their home and who was inspired by Kant and Goethe. Among the regular guests, there was the philosopher Høffding, the linguist Thomsen and the physicist Christiansen. A frequent topic of these disputations was a controversy between mechanistic and vitalistic or teleological approaches to the animate nature. In his father's laboratory, Bohr also often witnessed discussions on these issues with the pathologist Lang and the anatomist Chievitz (e.g. Pais 1993; Grygar 2014). Høffding describes Christian Bohr's position as follows: "He followed a line that requires the strict application of physical and chemical methods to physiology. Outside the laboratory he was a keen worshipper of Goethe. When he spoke of practical situations or of views of life, he liked to do so in the form of paradoxes and these were improvised as a rule" (Bohr 1972–2008 (CW 6): XXI). The point is that Niels Bohr's long-lasting search for, as he says, a new unity of knowledge lies in this really unusual approach. And through this approach, Bohr later solved his atomic model. Bohr gradually developed his complementary thinking also on the basis of his correspondence principle (Grygar 2014).

[4] Rubin was Bohr's step cousin and they often discussed psychological and philosophical problems (visual illusions, free will, mind-body distinction, possibilities of introspection etc.).

causally non-deducible like *wave* and *particle*; *mechanistic* and *teleological*; *vase* and *profiles of human head*; *quantum experimental arrangements* for exact measurement of momentum and for exact measurement of position; *molecular* and *evolutionary* definition of gene (for more examples see below). Their complementarity takes place in our thinking and in a situation which demands a new solution like in quantum mechanics. Moreover their complementarity happens within our preunderstanding of those notions and their everyday or scientific contexts (Grygar 2014).[5]

Complementarity became the climax of Bohr's long-lasting search for a new harmony and unity of knowledge "regardless of whether its surface manifestation is via such widely differing human instruments" used by "a biologist, a physicist, a philologist, and a philosopher" (Blædel 1988: 20).[6] For him, all scientific and non-scientific activities and communication depend on our everyday language, regardless of their extension with the help of physical-chemical, mathematical or special concepts. In addition, "we can by no means dispense with those forms of perception which colour our whole language and in terms of which all experience must ultimately be expressed" (Bohr 1972–2008 (CW6): 283). Bohr constantly emphasized that scientists in their own fields of study should have been concerned with conditions for using our concepts or notions for objective descriptions (Bohr 1972–2008 (CW10): 112; cf. Pattee 1979: 220).

As Bohr's last assistant Petersen remembers, Bohr emphasised that we are not able to look "beyond" our words. Thus "we are suspended in language. Our task is to communicate experience and ideas to others" and all we can do is to work within this conceptual frame, attempting to extend the possibilities of any description and secure its objectivity, which depend on the intersubjectivity of scientific communication. Hence Bohr did not deal with the problem of the so-called objective reality (with its own hidden parameters as for instance Einstein did), i.e. independent reality which would precede language, because "the word 'reality' is also a word, a word which we must learn to use correctly" (Petersen 1963: 10–11). He further pointed out that "there is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how nature *is*. Physics concerns what we can *say* about nature" (Ibid, 12).[7] Similarly there is no

[5] The non-sharp complementarity does not appear to correspond with Bohr's original idea of incompatibility, which he considered deeply in particular by means of physics. The complementarity of requiring pairs or opposites is relatively uninteresting in contrast with Bohr's conception of incompatible complements, which is a sovereign philosophical, scientific and epistemological problem. It is therefore desirable to continue dealing with this more interesting kind of complementarity (Grygar 2014).

[6] Bohr writes elsewhere: "Indeed, in renouncing logical analysis to an increasing degree, and in turn allowing the play on all strings of emotion, poetry, painting and music contain possibilities of bridging between extreme modes as those characterized as *pragmatic* and *mystic*" (Bohr 1972–2008 (CW10): 160).

[7] The famous discussions with Einstein reached their climax in 1935. These philosophical-physical disputes (based mostly on thought experiments) dealt with rethinking the Cartesian subject-object split and modern claims about logic, cognition, causality, explanation and the possibilities and conditions of observation. These questions are equally important for biological or biosemiotic research. One of the essential problems lies in the processes of measurement as such, their possibilities and resulting interpretation. Is it, for instance, possible to investigate nature and its properties (hidden parameters), which would be independent of us, our theories and measuring devices which interact with the investigated (phenomenon, object) and *influence* the measured? Is there the measured with its properties without us or before the act of measuring? Do not the measured phenomena originate in experimental conditions? Would this mean that measuring devices have nothing to influence or disturb? If we allow the existence of measured objects and their properties before the processes of measurement, do we learn of the original properties from the resulting data or are the properties influenced by the measurement? (Grygar 2014; Bohr 1972–2008 (CW7): 339–381).

'matter', 'numbers' or 'spin' in nature; those words are our theoretical and interpretative instruments.

Bohr applied the same reasoning to other sciences. Thus, for example, biology cannot be preoccupied with what living organisms *are*, but must instead explain "the position of *living organisms* in our picture of the world" (Bohr 1972–2008 (CW6): 300). Similarly, cells do not have, for example, 'genetic information', 'organic codes' or 'meanings' inherently, and only possess these features by virtue of our interpretations. Nevertheless, these notions help us improve the scientific explanation of the phenomenon of the living in our view of animate nature. Hence our descriptions of nature do not uncover the real essences of the phenomena under exploration, but endeavour to reveal "relations between the manifold aspects of our experience" (Bohr 1972–2008 (CW6): 296). Otherwise, as Pattee interprets Bohr, "all biological information originates from measurements" and there is epistemological complementarity "between a measuring device, represented as a sourced information, and the object of measurement represented by causal laws, structures or events". Simultaneously, "ordinary classical language concepts are all we have to ultimately interpret and communicate the results of our observations and our theories" (Pattee 1979: 218–219).

Bohr assumed that we usually work by attempting immense reductionism across all fields of study and within the increasing specialization in technology or science, but argued that this approach "implies the danger of prejudices" (Bohr 1972–2008 (CW10): 64). Modern science evidently provides "a deeper insight into our own Being and our place in existence", however it is only one of many assorted manifestations or levels of how to understand nature or Being (Bohr 1972–2008 (CW11): 414). Bohr realized that all the accumulated problems standing at the birth of quantum theory (the question of language, paradoxical descriptions or pictures of nature, the results of experiments, the problem of continuity-discontinuity and the principal role of conditions of the observation-observable distinction) show that "it is just this state of affairs which primarily gives to the problems in question their general philosophical interest" (Bohr 1972–2008 (CW6): 283). Therefore it was also necessary to address other fields of study, for example, "psychology, or even […] epistemological problems with which already thinkers like Buddha and Lao Tse have been confronted, when trying to harmonize our position as spectators and actors in the great drama of existence" (Bohr 1972–2008 (CW10): 60).

Just as Husserl's and Heidegger's phenomenology contemplates the relation between our activities and their objects intentionally and hermeneutically (Husserl 1970, 1983, 2001; Heidegger 1962), Bohr realized that it is not possible to draw a strict dividing line between activities or processes of sensation, thinking, observing or measuring on the one hand, and their objects, i.e. some tone, thought, observable or measurable on the other, although we know they are not the same. For instance, we are not entirely able to determine or distinguish between what belongs *on the side* of an observer with his/her various preunderstandings and motivations (with which the observer approaches proposing theories, the production of instruments etc.) and what belongs *on the side* of observable or measurable systems.

Quantum theory discusses the relation between our activities and their objects from the perspective of interactive systems (Grygar 2014; cf. Pattee 1978: 194; 1979: 220–221; 2008: 118–119). Any attempt to determine, for example using quantum measurements, the interaction between a measurable system and a measuring device (because of uncontrollable exchange of energy and momentum) would require the installation of an additional device. This would again interact with the system under control and so on. This case

> in fact discloses only an essential inadequacy of the customary viewpoint of natural philosophy for a rational account of physical phenomena of the type with which we are concerned in quantum mechanics. Indeed the *finite interaction between an object and measuring agencies* conditioned by the very existence of the quantum of action [Planck constant – author's note] entails – because of the impossibility of controlling the reaction of the object on the measuring instruments if these are to serve their purpose – the necessity of a final renunciation of the classical ideal of causality and a radical revision of our attitude towards the problem of physical reality (Bohr 1972–2008 (CW7): 293).[8]

Heelan, who is both a quantum theorist and a hermeneutical phenomenologist, maintains that any "measurement is a hermeneutic performance, like the playing and replaying of a game or like a musical or theatrical performance" (Heelan 2002: 450). Scientist and historian of science Katsumori adds: "Neither of the two complementary relata, neither of the roles of 'spectator' and 'actor', has priority over the other" (Katsumori 2011, V). With Pattee we can say that every "explanation of events requires both an objective, causal representation and a subjective, prescriptive representation that are complementary" (Pattee 1978: 191). To allow these positions after several centuries of development of the modern objective science, has, as Bohr stressed, a fundamental impact on our conception of *understanding*, *explanation* and *unity of knowledge*. The new situation disclosed that "in the process we may have to learn what the word 'understanding' really means" (Heisenberg 1971: 41). If we want to explain what explanation itself is, we must be aware that any explanation means reduction of complex phenomena to more simple ones and "any analysis of the very concept of an explanation would, naturally, begin and end with a renunciation as to explaining our own conscious activity" (Bohr 1972–2008 (CW10): 35).

As soon as Bohr started to apply complementarity as a new framework for the unity of knowledge outside of the realm of quantum theory, he fully realized that beyond various analogies between quantum theory and psychology or philosophy "lies not only a kinship with regard to the epistemological aspects, but […] a more profound relationship […] hidden behind the fundamental biological problems" (Bohr 1972–2008 (CW6): 298; cf. Pattee 1979).

[8] Thus an object and measuring device cannot be contemplated in a classic way (in classical physics they can be *fully* isolated or independent on each other during the processes of measurement). The very notion of object hence became problematic and Bohr therefore started to focus on a further elaborated explication of the notion of phenomenon and its application "exclusively to refer to the observations obtained under specified circumstances, including an account of the whole experimental arrangement" (Bohr 1972–2008 (CW7): 378, cf. 335).

Bohr's Complementary Approach to the Phenomenon of the Living

Bohr wrote six principal and variously transformed contributions about philosophical and epistemological questions of biology between the 1930s and 1960s.[9] In a manner analogous to quantum theory, he attempted to disclose the conditions by which biological research is possible at all and the epistemological framework within which it may achieve a complex description.[10] With this approach, Bohr not only influenced Delbrück in the 1930s (who switched from physics to biology) but also, among others, young zoologist and postgraduate researcher James D. Watson, who made use of Bohr's work to apply physical ideas to biology in the 1950s; a time when biologists were distrustful of Watson's notions (Delbrück 1963, 1976; Watson 1962).

From his youth, Bohr was pre-occupied by the epistemological paradox his father, the experimental physiologist, underlined in general descriptions of the meaning of life or animate nature. Namely, the more we pursue the experimental and chemical-physical explanation of animate nature, the more essential features of the living are lost in this description. And on the contrary, the more we pursue only teleological, qualitative or verbal descriptions of the living, the more we lose comprehension of the results, which can be shown only through a mechanistic or experimental approach (Grygar 2014). Bohr's ambition was to establish a scientific or epistemological framework which would confront this paradox without lapsing into either of two extreme positions, i.e. materialism or mysticism (cf. Bohr 1972–2008 (CW10): 64). After 1927, he approached this task through the idea of complementarity, and, as Folse noticed, Bohr "considered his attempt to resolve this dispute to be in some fashion a payment of the intellectual debt he owed his father" (Folse 1985: 183).

The idea of complementarity proposed by Bohr is based on a huge combination of variously repeated issues mentioned in the previous chapter concerning the *psycho-physical parallelism*, *spectator-actor* circle, *suspending in language* and the *epistemological lesson of quantum theory.* In biological research there is an essential complementarity of an experiencing observer-subject as a priori living creature and *ex post* scientific objective articulation of the living. It is impossible to explain what life itself is, since any description of living nature already implies and presupposes life and the living. Moreover, a scientific attempt to incorporate the active observer into the description means that a new non-objectivisable observer appears and this situation is similar to the problem with adding additional devices for the controlling interactive systems in atomic physics. Thus

[9] In Bohr 1972–2008, CW10: *1.* Light and life (1933): 28–35; *2.* Biology and atomic physic (1937): 49–62; *3.* Physical science and the problem of life (1957): 116–123; *4.* Quantum physics and biology (1960): 125–132; *5.* Physical models and living organisms (1961): 134–137 and *6.* Light and life revisited (1962): 164–169.

[10] Bohr's frequent accent on the interactive systems, spectator-actor frame, common language and conditions that precede or constitute any explicit language or objective description is pivotal for his complementarity and approach to the biological questions for it is essentially penetrated with Bohr's notion of two kinds of phenomenon and language (Grygar 2014). Although Bohr never explained this dilemma in detail I want to remark that it is possible, from the phenomenological point of view, to distinguish in Bohr's philosophy of science *ontic* phenomena (*intentional objects* or *contents*) in terms of Husserl's intentionality (Husserl 1970, 1983, 2001) and *ontological* non-objectivisable phenomena (*existentialia*) in light of Heidegger's hermeneutic phenomenology (Heidegger 1962). This distinction is nearly linked with a distinction between *predicative* (*apophantic*) and *pre-predicative* (*existential-hermeneutical*) dimension of language within Heidegger's hermeneutic phenomenology (Heidegger 1962).

> the distinction between subject and object, necessary for unambiguous description, is retained in the way that in every communication containing a reference to ourselves we, so-to-speak, introduce a new subject which does not appear as part of the content of the communication. It need hardly be stressed that it is just this freedom of choosing the subject-object distinction which provides room for the multifariousness of conscious phenomena and the richness of human life (Bohr 1972–2008 (CW10): 123).[11]

Bohr also referred to the question of psychological introspection. It is "clearly impossible to distinguish sharply between the phenomena themselves and their conscious perception". Thus "if we try to analyze our own emotions, we hardly possess them any longer" (Bohr 1972–2008 (CW10): 245).[12] In introspection we construct from flowing activity in time (implicit or a priori feelings), for example from hearing music, an object of introspection (reflection) and this objectivizing is already not the original experience of the music.[13] So, generally speaking, "words like contemplation and volition, referring to situations which are mutually exclusive, but equally characteristic of conscious life, have been used in a typical complementary manner since the very origin of language" (Bohr 1972–2008 (CW10): 152, cf. 159). This is again for Bohr, at a specific level, similar to the complementarity "between the experiences regarding the behaviour of atoms obtained under different experimental arrangements and described by means of different analogies taken from our usual ideas" (Bohr 1972–2008 (CW10): 245).

The problem of introspection is connected with Bohr's view of the traditional body-mind contradiction or divide. Bohr's position is again original: "What is complementary is not the idea of a mind and a body but *that* part of the contents of the mind which deals with the ideas of physics and the organisms and *that* situation where we bring in the thought about the observing subject." Accordingly, among other things, Bohr declared that "we have no possibility through physical observation of finding out what in brain processes corresponds to conscious experience". Once again, this is similar to "the relation between the information

[11] A philosopher Favrholdt concisely interprets Bohr's various notions about subject-object partition like this: "The concept of having knowledge presupposes the existence of the subject, which therefore cannot itself form part of our knowledge. Whatever I perceive, I shall never be able to perceive or analyze the subject – myself. A subject perceiving itself is just as impossible to imagine as is a drawing containing itself as an element." (Favrholdt 1999: 8). Bohr got the idea of subject and object entanglement (among other things) from his favourite Møller's book for teenagers "En dansk Students Eventyr". In his lectures or texts, he used parts of the book as an example of the problem of the elusiveness of I, language or interactions in measurement processes and people who came to Copenhagen to work in *Universitetets Institut for Teoretisk Fysik* (from 1965 *Niels Bohr Institutet*) "had to", as Rosenfeld remembers, read that book to improve their Danish and learn more about Bohr's peculiar dialectical thinking (Grygar 2014; Rosenfeld 1967: 121).

[12] Bohr also writes elsewhere that already "Indian thinkers understood the logical difficulties in giving exhaustive expression to such wholeness. In particular they found escape from apparent disharmonies in life by stressing the futility of demanding an answer to the question of the meaning of existence; realizing that any use of the word 'meaning' implies comparison, and with what can we compare the whole existence?" (Bohr 1972–2008 (CW10): 160).

[13] Bohr's issue can be approximated also by means of a famous Augustin's expression: "What then is time? If no one asks me, I know [or understand; in Latin *scio* - author's note]: if I wish to explain it to one that asketh, I know not […]." (Augustine 2005: 200). If we are to explicitly answer, we do not know what exactly we are to answer, as if we seemingly did not understand what time is and we provide only various concrete or factual reductions of superposition of implicit understanding time; however the original understanding does not disappear. Similarly Heidegger shows difference between ontological non-objectivisable understanding (*Verstehen*) and explicit understanding or interpretation (Heidegger 1962).

we can obtain concerning the structure of cells and the effects this structure has on the way organic life displays itself" (Bohr 1972–2008 (CW10): XLVIII and XLVII).[14]

Among other parallels between quantum theory and biology, Bohr pointed out that attempts to explain light and biological life are subject to analogous constraints. The phenomenon of light ("perhaps the least complex of all physical phenomena") cannot be captured by means of a coherent mechanical explanation (because of the impossibility of the "complete causal description") and can only be captured complementarily (with two exclusive pictures of nature, i.e. wave and particle). The phenomenon of the living, similarly, cannot be explained from a physical-chemical perspective because of immense "diversity of which is far beyond the grasp of scientific analysis" (Bohr 1972–2008 (CW10): 29). Hence Bohr stated that the phenomenon of the living or

> the existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting point in biology, in a similar way as the quantum of action, which appears as an irrational element from the point of view of classical mechanical physics, taken together with the existence of the elementary particles, forms the foundation of atomic physics. The asserted impossibility of a physical or chemical explanation of the function peculiar to life would in this sense be analogous to the insufficiency of the mechanical analysis for the understanding of the stability of atoms (Bohr 1972–2008 (CW10): 34).

Although Bohr made several analogies and parallels between quantum theory and biology, his aim was not to explain biological phenomena via quantum theory (as Jordan, for example, did[15]). In fact, organisms are compounds of atoms and molecules and physical and chemical phenomena are therefore interwowen on that level. Chemistry (at a molecular level) and quantum theory (which also enables the examination of the sub-atomic level) are to a certain extent complementary and the same holds for relation between quantum-mechanical and biological descriptions. For example "any attempt at space-time location of the electrons in atoms and molecules would demand an experimental arrangement prohibiting the appearance of spectral regularities and chemical bonds" (Bohr 1972–2008 (CW10): 166). Or vice versa as Delbrück stated in a letter to Bohr: "An experiment for preparing a chemical compound (a macroscopic experiment!!) is complementary to an experiment for measuring the orbits of the electrons generating the bond." And from the viewpoint of biological research, Delbrück further sum up Bohr's notions that

> the assumptions having to do with the causal order of biological phenomena may in part stand in formal contradiction to the laws of physics and chemistry, because experiments on living organisms are *certainly* complementary to experiments

[14] Heisenberg writes about this in a different way: "One could at the same time assume, as Bohr has suggested, that our knowledge of a cell being alive may be complementary to the complete knowledge of its molecular structure. […] In biology it may be important for a complete understanding that the questions are asked by the species man which itself belongs to the genus of living organisms, in other words, that we already know [as implicit non-objective preunderstanding – author's note] what life is even before we have defined it scientifically [or expressed it in everyday reflection – author's note]" (Heisenberg 1958: 104, 107).

[15] Although Jordan did not have the same opinion of the problems of biology as Bohr, he, nevertheless, often argued with Bohr's images. This led to the suspicion, particularly among critics of Bohr's, that Bohr holds a version of vitalism (Grygar 2014; Jordan 1934, 1935).

establishing physical and chemical processes with *atomic* precision (Delbrück 1934: 468[16]).

Mechanistic applications and limitations of chemistry, physics and quantum theory for describing the phenomenon of the living are connected, as Favrholdt expressed it, with *metabolical* and *thanatological* arguments (Favrholdt 1999: 11). The demand for exhaustive observation or description of the living would require taking into account the role which single atoms perform during reproduction, metabolism and in self-preservation of organisms.[17] For biology to deal with the atomic level, scientists would have to interrupt exchangeable processes in living organism and eliminate any vital or feeling activities "since the interference necessitated by an observation which would be as complete as possible from the point of view of the atomic theory would cause the death of the organism" (Bohr 1972–2008 (CW6): 300).

Thus the phenomenon of the living displays itself within a set of conditions that preclude a thoroughly complex analysis of the living, on account of "the impossibility of regarding an organism as a well-defined system of material particles like the systems considered in any account of the ordinary physical and chemical properties of matter" (Bohr 1972–2008 (CW10): 61) or any machines.[18] Quantum mechanics is unable to explain how a certain arranged whole of atoms is able to adapt to its surroundings, in the way as living organisms are capable of doing it (Bohr 1972–2008 (CW6): 299).

Yet sufficiently comprehensive biological research and an integral description of the organism can, according to Bohr, be seen in complementarity between two ways of exploration. One approach would not allow separation of the organism from its natural functioning in surroundings and the second, chemical-physical approach, which necessarily needs to isolate the organism (or its parts) from the surroundings (or from the other parts). For Bohr, the fundamental or non-reduced connection of the living organism with its surroundings is similar to the situation which arose in quantum mechanics as questions concerning quantum entanglement, nonlocality and quantum holism.[19]

Because of specific features that we come across in living organisms and which are absent in inorganic nature, it is important for the reconciliation of "the laws of physics with the concepts suited for a description of the phenomena of life [...] to examine the essential difference in the conditions of the observation of physical and biological phenomena" (Bohr 1972–2008 (CW10): 60 and 61; cf. Pattee 1979). Essential features

[16] In that Delbrück's letter to Bohr in 1934 he concisely summed up Bohr's approach to the phenomenon of the living from the limits and perspectives of relations between physics, chemistry and biology or quantum mechanics.

[17] Bohr says that "it is typical of biological researches, however, that the external conditions to which any separate atom is subjected can never be controlled in the same manner as in the fundamental experiments of atomic physics. In fact, we cannot even tell which atoms really belong to a living organism, since any vital function is accompanied by an exchange of material, whereby atoms are constantly taken up into and expelled from the organisation which constitutes the living being" (Bohr 1972–2008 (CW10): 34).

[18] Bohr notes that "the whole history of organic evolution presents us with the results of the trying out in nature of the immense possibilities of atomic interactions", and therefore, among other things, that "organic life is a manifestation of nature's resources far beyond those used for the construction of machines" (Bohr 1972–2008 (CW10): 151).

[19] Adding this standpoint: "In every experiment on living organisms, there must remain an uncertainty as regards the physical conditions to which they are subjected, and the idea suggests itself that the minimal freedom we must allow the organism in this respect is just large enough to permit it, so to say, to hide its ultimate secrets from us" (Bohr 1972–2008 (CW10): 34).

and peculiar regularities which are related to the phenomenon of the living thereafter "might stand in a relationship of exclusion" to strict application of the physical-chemical concepts suitable to the description of inanimate nature or various machines (Bohr 1972–2008 (CW6): 300–301).[20]

To sum up Bohr's complementary approach to the phenomenon of the living, we can state that the insufficiency of the mechanistic explanation is revealed in the extraordinary arrangement and the performance of the living organisms. To explain animate nature the aim is not only to arrive at a chemical-physical description of things like reproduction, metabolism and adaptation, but also to understand the naturally developing unity, dynamic uniqueness of the living and human capacities for contemplation, remembering, decision-making etc. In researching the deeper problems of animate nature we are not only concerned with consciousness (which "is inseparably connected with life" and corporality) but also "with the freedom and power of adaptation of the organism in its reaction to external stimuli" (Bohr 1972–2008 (CW6): 252). We therefore have to reckon with the fact that "the recognition of relationships of wider scope will require that the same conditions be taken into consideration which determine the limitation of the causal mode of description in the case of atomic phenomena". We should thus appreciate "that the very problem of the distinction between the living and the dead escapes comprehension in the ordinary sense of the word" (Bohr 1972–2008 (CW6): 252–253).

However, despite all these limits on the examination of animate nature, Bohr was an advocate of a strict examination, after his father, and a pupil of the Newtonian ideal of science (Bohr 1972–2008 (CW10): 34). Scientists, he claimed, should try to penetrate deeper to the unexplored areas of the animate nature on the basis of the achieved laws of physics and chemistry and should not introduce any vitalistic or mystical images to the research. It is no wonder then that Bohr was, just like others in 1953, thrilled by the discovery of the three-dimensional structure or double-strand model of DNA. He discussed all the details of this discovery with a young biologist from Copenhagen.[21] On the other hand, Bohr's fundamental-epistemological standpoint on the question of life remained the same.[22]

He wanted to demonstrate that a mere chemical-physical description based on a subject-object division is not enough for a complex or detailed description of the phenomenon of the living, but that a complementary approach is required. This must supplement single-sided structural or mechanistic explanations with a teleological standpoint (which shapes our preunderstanding of the functions of organisms or animate nature) and an understanding of the living in its manifesting self-organization,

[20] Otherwise: "The strict application of those concepts which are adapted to our description of inanimate nature might stand in a relationship of exclusion to the consideration of the laws of the phenomena of life" (Bohr 1972–2008 (CW6): 300–301). In *Biology and Atomic Physics* Bohr writes this: "We are led to conceive the proper biological regularities as representing laws of nature complementary to those appropriate to the account of the properties of inanimate bodies in analogy with the complementary relationship between the stability properties of the atoms themselves and such behaviour of their constituent particles as allows of a description in terms of space-time coordination" (Bohr 1972–2008 (CW10): 61).

[21] See for example Bohr's letter to Delbrück from 19 November 1959 (Bohr 1972–2008 (CW10): 486) or *Light and Life Revisited* (Bohr 1972–2008 (CW10): 164–169).

[22] In the article *Physical Models and Living Organisms* of 1961, he similarly writes that it is obvious – despite the great discoveries and experimental progress of molecular biology in recent years – that fundamental features of living organisms are not comparable with anything because they are the result of "the whole history of organic evolution, reveal potentialities of immensely complicated material systems, which have no parallel in the comparatively simple phenomena studied under reproducible experimental conditions" (Bohr 1972–2008 (CW10): 137).

including the interaction with the environment and the one who is analyzing.[23] In the words of Pattee: “In so far as structural descriptions are accurate (objectively) they do not refer to function, and in so far as functional descriptions are accurate (subjectively) they do not refer to structure” (Pattee 1978: 195). According to Bohr, it is essential to acknowledge that “only in the renunciation of an explanation of life in the ordinary sense do we gain the possibility of taking its characteristics into account” (Bohr 1972–2008 (CW10): 92).

Complementarity of Mechanistic, Biosemiotic and Hermeneutic Description

This part outlines Bohr’s epistemology of complementarity via three chosen descriptions of the phenomenon of the living: a) mechanistic (molecular or cell biology), b) Barbieri’s version of biosemiotics, as developed into his new science of life titled *code biology*, and c) Markoš’s version of hermeneutic biosemiotics, as influenced by Heidegger’s phenomenology. Since I am not specialist in molecular biology or biosemiotics and am familiar with hermeneutics from a Heideggerian point of view, every biosemiotician should take this section as a simple model example that can be changed and evolved on the basis of subtle expert analyses.

1. The mechanistic approach, more precisely molecular or cellular biology (e.g. Alberts et al. 2004), explains living organisms and cells by reference to complicated molecular structures and processes that are regulated by mechanically conceived genetic code, “the only organic code which is officially recognised in the textbooks of modern biology” (Barbieri 2003: 96). The presumptions and technical language featured within this chemical-physical approach do not contain concepts, functions or the other above-mentioned possibilities for understanding the complicated performances of cells or the living.
2. Like Bohr, biosemiotics acknowledges that a mere mechanistic description of the phenomenon of the living is highly reductive. As two representative biosemioticians Pattee and Hoffmeyer claim respectively:

> The enormous success of modern molecular biology, in attaining detailed structural descriptions of living systems, temporarily eclipsed the problems of explaining the functional processes of self-description, self-construction and self-control that are characteristic of all living systems at all levels of organization (Pattee 1978: 196).

[23] Elsewhere in Bohr: “Because of their immense complexity it is not surprising that the organisms reveal properties and potentialities, which are in striking contrast with those exhibited by so-called inanimate matter under simple reproducible experimental conditions. It is on this background that such notions as purposefulness and self-preservation, referring to the behaviour of organisms as entities, have found fruitful application in biological research” (Bohr 1972–2008 (CW10): 151). McKaughan correctly shows that “Bohr did not think that we can simply add more concepts to expand current physics and chemistry. His point was precisely that the required teleological concepts were *incompatible* with the *correct* physical-chemical description and that some biological phenomena are not intelligible in solely mechanical terms” (McKaughan 2005: 517).

> All processes that take place in animate nature at whatever level, from the single cell to the ecosystem, should be analyzed and conceptualized in terms of their character as sign processes. This does not deny any of the well-established physical and chemical laws; it is simply claimed that life processes are part of – and are organized in obedience to – a semiotic dynamic. Biosemiotics, then, is concerned with the sign aspects of the processes of life itself, not with the sign character of the theoretical structure of life sciences (Hoffmeyer 2007: 4).

Sebeok further emphasizes that "there can be no semiosis without interpretability – surely life's cardinal propensity – semiosis presupposes the axiomatic identity of the semiosphere with the biosphere" (Sebeok 2001: 68). In other words: "An object is semiotic if it is in interpretation. Interpretation, according to the contemporary biosemiotic view, starts with the very process of life" (Kull 2011: 118). Generally, the biosemiotician's endeavour to consider all living beings as semiotic systems is a bold and creditable cross-disciplinary project. It tries to integrate different and often incompatible – in light of theoretical principles or concepts – branches of study from natural sciences to humanities.

Nevertheless, according to Barbieri's version of biosemiotics (Barbieri 2007), the claim of biosemiotics is to be a genuine natural science. He agrees that life is not just an execution of a program written in the DNA, but "that life is based on semiosis, i.e., on signs and codes" (Barbieri 2008a: 577). On the basis of experimental and mathematical results he wants to show that biosemiotics studies signs and codes as "fundamental natural entities that are objective and reproducible as the physical quantities" and accordingly he treats the cell as a rich semiotic system (Barbieri 2007: 179). However, in contrast to the interpretative frame of biosemiotics (where meaning is produced by interpretation) Barbieri asserts that organic meanings or signs are defined on the level of cells by coding without requirement of any interpretation, and therefore biosemiotics does not belong to humanities. He also claims that organic codes, memories, signs or meanings do not fit (so far) with established chemical and physical descriptions. For this reason, Barbieri calls for "new theoretical framework" where these concepts "are not put aside as metaphorical entities but are defined by operative procedures […]" (Barbieri 2007: 179). He shows that not only human or culturally conventional codes, but all codes, including the genetic one, are sets of rules and "are not dictated by the laws of physics and chemistry" (Barbieri 2014b: 168). Codes and laws are mutually incompatible because codes are historically conditioned conventions, independent of material structure. Moreover, they "require not only energy and information" but also meaning as "a new physical quantity" (Barbieri 2003: 94) that "*is an entity which is related to another entity by a code*" (Barbieri 2015: 26). Therefore the codes mechanically make it possible to "add meaning to information" and "connect two independent worlds" (Barbieri 2003: 96) such that "anywhere there is a code, be it in the mental or in the organic world, there is meaning" (Barbieri 2015: 26). For example, the genetic code makes it possible to connect "worlds of nucleic acids and proteins" or the Morse code makes it possible to connect conventional "combinations of dots and dashes with the letters of the alphabet" (Barbieri 2003: 96). With Barbieri's new theory, there are two different evolutionary mechanisms in biology: a) current "evolution by natural selection through copying" and b) new "evolution by natural conventions through coding" (Barbieri 2003: ix, cf. 178).

At present, however, it seems that Barbieri's creditable improvement is not compatible with a paradigm of cell biology; we can say that both approaches are to a certain extent complementary. And moreover, after several years of tough discussions with biosemioticians about the main aims and definitions of basic concepts, Barbieri came to the conclusion that "biosemiotics could not be reconciled with science and" that "the only way to introduce meaning in biology", without using an interpretative framework, is his "new approach that became known as Code Biology" (Barbieri 2014a: 239; cf. 2014b, 2015).

3. From Markoš's hermeneutic standpoint, inspired by hermeneutic phenomenology, [24] even Barbieri's objectivistic approach does not suffice for a complex understanding of the phenomenon of the living. In a review to Barbieri's book (Barbieri 2003), Markoš and colleagues (2008) write:

> Professionals aiming to understand life are divided into approximately two groups. Most biologists are found in the first of these groups – they presuppose that living beings are composed of objectively identifiable, describable and calculable entities which are governed by invariable natural laws. The second group comprises in particular the representatives of humanities who emphasize contextual and historic aspects of the "Life-world" [in the sense of Husserl's *Lebenswelt* encompassing manifestation of all the living – author's note], i.e. those properties which are somehow "additional" to life, contrary to objective constructs of chemistry and physics. These two groups will probably never come to an agreement and their discussion end by shrugged shoulders […]. Attempts to bridge the gorge between the two approaches are usually unsuccessful and denounced by both parties (Markoš et al 2008: 51).

It is not made explicit in the review, or in Markoš's epilogue to the translation of Barbieri's book (Markoš 2006; Barbieri 2006), that Barbieri would belong mainly to the first group of scientists, but from both texts and Barbieri's argumentation it seems so. In short, although Barbieri made a pivotal contribution to the understanding of life – trying to enrich biology with the concept of meaning and codes as historically constituted conventions or the evolution by natural conventions – he still does not bridge natural sciences and humanities. Markoš and colleagues, for example, show that in principle Barbieri deprived meaning (or code) of the semantic, semiotic and hermeneutic contexts of the *Life-world*, in which meaning and language (including scientific

[24] Markoš is familiar with Heidegger's hermeneutic phenomenology and with his non-objective approach to the phenomenon of the living outlined in *Being and Time* (Heidegger 1962) and analysed at large in the lectures named *The Fundamental Concepts of Metaphysics* (Heidegger 2001). Markoš translated to Czech several paragraphs from the second part of *The Fundamental Concepts of Metaphysics* which deals with Heidegger's *privative interpretation* and wrote commentary to it (Markoš 2010a: 61–96). Markoš is also inspired by Heidegger's dual conception of language, i.e. *pre-predicative* (*existential-hermeneutical*) and *predicative* (*apophantic*) from *Being and Time* and *The nature of language* (Heidegger 1982). Markoš and Ovčáčková translated to Czech excerpts from of *The nature of language* and wrote a commentary on it (Markoš and Ovčáčková 2010: 97–142). As to biology, for example in *Being and Time*, Heidegger claims that a biological attempt for determination of the essence (*Wesen*) of the phenomenon of the living cannot be based exclusively on something beyond us, because biology is one of many interpretative capabilities and historical articulations of *Being of man* (*Da-sein*) whose fundamental structure is *Being-in-the-world*.

terminology) are historically constituted. Barbieri persists in using the term *meaning* in the fashion of the mechanistic approach of traditional natural sciences. The same has happened to such concepts as *information* or *translation* in current biology. Markoš and colleagues further argue that even at the level of the cell – provided it is a real semiotic and living system – there exists an interpretation. Meanings are not constituted on the basis of some blind code (or syntactic rule) since there is functioning of a cell which resists any mechanism and simultaneously provides any mechanism, meaning, code etc. in the evolutionary process. It is possible to say (although not using the technical terminology of biology) that the cell (or embryo) is *intentional*, i. e. *experiences* something, *remembers* and *knows* what to do and what to build, for example during protosynthesis or morphogenesis (Markoš et al 2008). Therefore cells and more generally living beings are constantly *taking care* of themselves and are neither mere passive machines driven in evolution by outer forces nor mere "application of known principles of physics and chemistry" (Markoš 2006: 214). In other words, according to Markoš and in spite of the undoubted virtues of Barbieri's approach, Barbieri's book can be read as a transformation of life or the living into a kind of programmed machines or complicated computation systems that are not engaged with themselves and thus can't decide or project themselves, because they are manipulated somehow *from behind* through *organic memories*, *organic codes*, *physical forces* and *programmes* (Markoš 2006).

It appears that Barbieri is still strongly towed on the one hand by the amazing advantages of mathematics, mechanics and dynamics developed since the 17th century, and on the other hand by the substantial disadvantages of their application to the phenomenon of the living. A Czech authority on the history of science, Zdeněk Horský, concisely described this dilemma:

> Finally, mathematical formulas were found for managing the movement of bodies and it became reasonable to expect mathematics also to succeed in other physical disciplines. If a truly mechanically formulated law is to apply unconditionally, a body [or any living body and nowadays a cell – author's note], whose behaviour is described by that law must also be subject to it unconditionally and unequivocally. In the course of a physical event the body must not add anything to this action from its will, the body must become dead. Mechanics celebrated its successes only when it had pushed the life out of nature. Life sciences naturally paid the highest toll (Horský 1980: 100; cf. Markoš 2002, 2006).

As I have described in the previous section, Bohr realized this long-lasting paradox and claimed (on the basic of his epistemological lesson of quantum theory) that the existence of life is a priori non-explicable facticity we constantly participate on. Therefore, to treat the cell or the living being in its livingness, we cannot only do with the subject-object division and physical-quantum-chemical laws or with code biology. Moreover, the Bohrian lesson says that matter, objective reality and electrons or, in biology, meaning, organic codes, signs and genetic information do not exist inherently in nature or in cells independent of us and our interpretative activity. Physics, chemistry and biology deal with our manifold experience of nature or experiments and are necessarily expressed in language(s). Therefore, complementarily to any objective science about life (reducing the phenomenon of the living to the measurable or describable objects, qualities or entities), we also need to treat those "additional" properties or, strictly speaking, non-objectively identifiable conditions and a priori capabilities of the living we have been suspended in for billions years.

Similarly, Markoš analysed this dilemma (Markoš 2002, 2006; Markoš et al 2009) and declared that both natural sciences and humanities – provided that they are objective sciences – cannot entirely understand the phenomenon of the living because "living beings are situated in between them" (Markoš 2006: 223). The reason is that "some manifestations of life are inadmissible for scientific *method*" (Markoš 2010b: 214), and thus it is desirable to find another mode of explanation. Markoš has found it in Heidegger's non-objectivistic phenomenological method which is in principle incompatible with any scientific method. While Heidegger speaks about *Dasein*'s fundamental hermeneutics (we live and explicate life in the first-person), Markoš has tried to extend this hermeneutic capability to the ontological structure of all the living. It is not the traditional hermeneutics dealing with a subject of study or with life, but fundamental "hermeneutics *by* the living" (Markoš 2010b: 215; cf. Markoš et al 2009; cf. Bohr 1972–2008 (CW10): 125–137). This hermeneutic situation *by* Dasein and *by* the living understanding and taking care of itself can be express in the following way:

> In understanding, as an *existentiale*, that which we have such competence over is not a "what", but Being as existing. The kind [the mode – author's note] of Being which Dasein [the living – author's note] has, as potentiality-for-Being, lies existentially in understanding. Dasein [the living – author's note] is not something present-at-hand [objectively present – author's note] which possesses its competence for something by way of an extra; it is primarily Being-possible. Dasein [the living – author's note] is in every case what it can be, and in the way in which it is its possibility (Heidegger 1962: 183; cf. Markoš et al 2009).[25]

Markoš strives to show that it is necessary to take into account hermeneutics *by* cells and larger dynamic ensembles (as morphological or ontogenetic processes) and their relationship to what is possible to record in discrete and easily copyable characters, for instance a genotype (Markoš 2002, 2006, 2015a, b). Moreover, statistical work with the rules of transferring genetic traits of parents on their offspring or work with various DNA recombinations etc. are only simplified cases examined in a lab (Markoš ibid; cf. Bohr 1972–2008 (CW10): 148–153). In these pieces of scientific research there is no understanding of the immanent functioning of the living which enables, during evolutionary development, all objectivisable processes. It means that we need to study evolutionary development not only in terms of accidental or blindly selected steps but also from respect of hermeneutic performances of the living that understands itself, projects itself or takes care of itself (no matter if this is its intention or not). Thus we need understanding of 'something' (not objects as codes, signs, meanings, measurable or observable parameters etc.) that Heidegger calls existential-ontological phenomena or *existentialia* (Heidegger 1962, cf. footnotes 10, 11, 12, 13). Simultaneously we, who constantly participate in our corporality and spirituality and perform countless reflections or research on concretizations and irreversible collapses of hermeneutical

[25] The question (from the perspective of hermeneutic phenomenology) is whether we can consider other than human creatures in light of hermeneutic performances (whether there are phenomena to it in phenomenological meaning of the word).

performances of the living, we are their part as well (Markoš 2002, 2010a, b, 2015a, b; Markoš and Ovčáčková 2010; cf. Bohr 1972–2008 (CW10): 164–169).

In such a view the life of a cell, populations of species etc. is based on self-understanding and every intentional activity and conduct is projected and thus interpreted by that in their own corporal and historical experiencing. Since the living is a hermeneutic and semiotic *structure*, the evolutionary process is not dictated solely, for example, by mutation and selection. This does not mean denying that in evolution some hermeneutic functioning or manifestations of the living have become automated (as we often do in our everyday activities), or have turned into mechanical structures which can be accurately explained by means of molecular or code biology. Nevertheless, "we cannot reach the essence of the living by automated mechanisms" (Markoš 2010b: 225).

Markoš and colleagues consider the situation in its entirety, and in agreement with Bohr's complementarity, they draw a conclusion: "When "life is at stake", we probably have to settle for the fact that we will always have two [or more – author's note] incompatible – and still truthful – descriptions" (Markoš et al. 2008: 51). This crucial epistemological insight (contradicting a traditional logic or rationality of modern sciences) enables us to establish "a general theory of evolution valid for *all* life" which works with methods, models and notions from both biology and the humanities (Markoš 2015b: 83).

In accordance with Bohr's approach, Markoš's conception could be rendered in a way that offers a complex understanding of the phenomenon of the living without imposing philosophical, hermeneutic and quantum mechanical etc. methods (coming from different contexts) on biology or creating a new alternative to the well-established molecular and cellular biology. Creating such an alternative would not be beneficial to highly specialized research which must be in principle reductionistic; the same holds naturally for technical scientific terminology. Bohr and Markoš try to highlight the ontological non-reducible *spectatorship-actorship* levels or unique exclusivity of the observer (interpreter) as an a priori living being on the one hand and the subsequent everyday or scientific interpretation of the living on the other. Both authors thus make use of the epistemological framework of complementarity (even though Markoš does not use this term) in thinking and research, which can be demonstrated via the following diagram (see Fig. 1).

For obtaining an elaborate complex understanding of the phenomenon of the living, there can be, for example, three equally necessary and true but different, or mutually incompatible, models, theories, notions or languages (*La*, *b*, *c*). *La* can represent the language and specialized approach of biology. *Lb* can represent various biosemiotics approaches and *Lc* can represent various hermeneutic approaches. *La', Lb'* and *Lc'* advert to contexts which in some measure intervene or influence crosswise those three languages and approaches. Each subtle language or specialized conception makes accessible from its own point of view some features, which the others eliminate or only refer to. And finally, *L0* is a Bohrian dimension of *spectator-actor-in-existence* (in which we are continually suspended) or Heideggerian dimension of *Being-in-the-world* (fundamental structure of *Dasein*) as non-objective (pre-predicative, *existential*) preunderstanding of our Being and life for our infinite interpretative behaviour, thinking, everyday or scientific descriptions (*La, b, c* …) that form multiple objective and learnable (predicative, *apophantic*), subsequently forgotten or unaware, preunderstandings for another explanations and descriptions of the world. Likewise any complementary descriptions or languages take place in the hermeneutic circle (*L0-La-Lb-Lc-L0-La-Lb-Lc* …; cf. Markoš et al 2009: 45–46; Heidegger 1962: section 32 and 63).

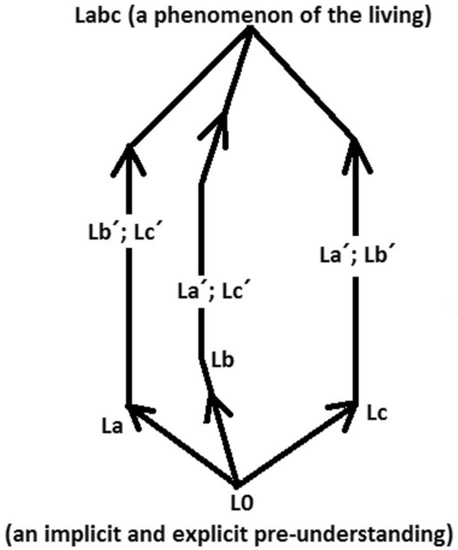

Fig. 1 Diagram of complementarity of languages, based on Heelan (Heelan 1988: 183)

Conclusion

The paper suggests that epistemology of complementarity can be a methodical and heuristic framework for testing the possibilities and limits of biosemiotics and its relation to other disciplines. It can also help to clarify whether biosemiotics can become one of the special sciences or continues to be a challenging cross-disciplinary project. In both cases, biosemiotics can work with a complementary understanding of the phenomenon of the living.

Complementarity enables various investigations and verifications/falsifications of compatibility/incompatibility or deducibility/irreducibility of notions, presuppositions, conditions and approaches both across different disciplines and within biosemiotics itself. Otherwise, as Pattee suggested, we can study complementarity within "three distinguishable types of irreducible forms: *hierarchic*, *nonlinear*, and *epistemic*" (Pattee 2001: 343). Other incompatible forms occur for example "at higher levels of function, cognition, and natural language" (Pattee 2001: 343). Complementarity is a flexible epistemological framework with which every scientist or teacher can learn to work in his/her field of study and simultaneously avoid falling into dangerous generalizations. Moreover, the complementarity framework does not deny changes and development of the theoretical base and terminology of the complementary models or descriptions. Those can be a) partially different, b) temporarily or partially incompatible as, so far, it is between cell biology and code biology or c) incompatible and mutually non-inferable as codes and physical-chemical laws; codes (thought, description) and hermeneutic functioning (instinct, volition); or, as elsewhere described by Markoš, incompatible as biological structuralism, inspired by philosophical structuralism, and neo-Darwinism (cf. Markoš 2002, section 4 and 5).

As I have mentioned, complementarity is not simply interchangeable for any scientific principle, specific duality or interpretation and similarly it is not simply interchangeable for the alternative or parallel (or pluralistic, cf. Kull 2011) approach to the scientific descriptions of nature. A problem with the alternative and parallel approaches lies, in my opinion, in these tendencies: a) the alternative approach can gradually replace, eliminate or mock a different or incompatible approach and b) parallel descriptions can only tolerate each other and not comprehend or work *pari passu* with each other. By contrast, the complementarity framework can produce a complex and subtle description.

In his last conversation with Thomas Kuhn and others (a day before he died), Bohr compared complementarity to the Copernican revolution, which has, step by step, become quite common in the education system. Bohr said: "I think it will be exactly the same with the complementary description" (Bohr 1962). In the end we can quote Delbrück's provocative expression: "In James Watson, we already have had an 'Einstein of biology'", so "we are still waiting for a 'Niels Bohr' in biology" (Fischer 2007: 676).

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