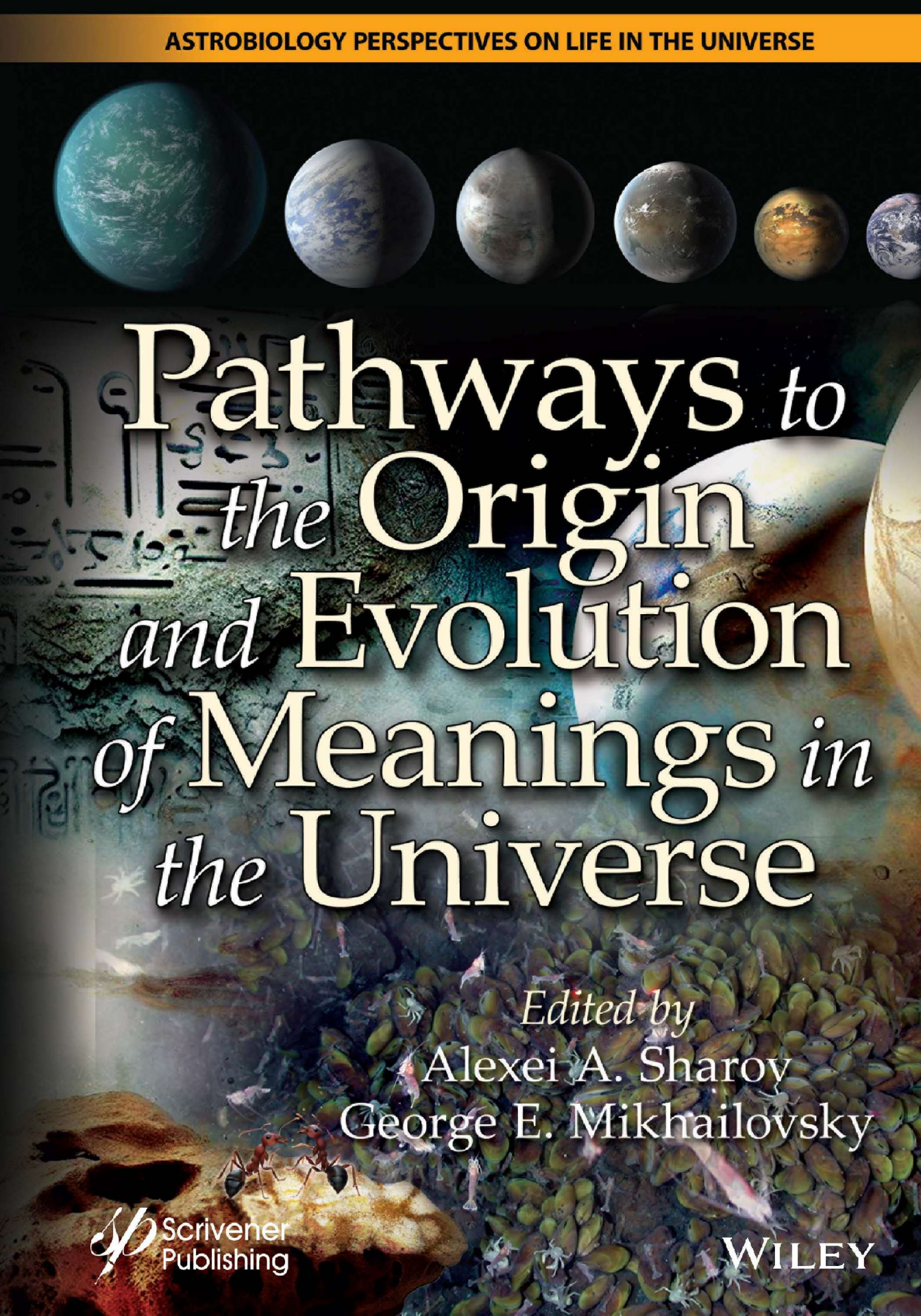




Pathways *to* *the* Origin *and* Evolution *of* Meanings *in* *the* Universe

Edited by
Alexei A. Sharoy
George E. Mikhailovsky

Pathways to the Origin and Evolution of Meanings in the Universe

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Astrobiology Perspectives on Life in the Universe

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Scope: In his 1687 book *Principia*, Isaac Newton showed how a body launched atop a tall mountain parallel to the ground would circle the Earth. We are both old enough to have witnessed the realization of this dream in the launch of Sputnik in 1957. Since then our ability to enter, view and understand the Universe has increased dramatically. A great race is on to discover real extraterrestrial life, and to understand our origins, whether on Earth or elsewhere. We take part of the title for this new series of books from the pioneering thoughts of Svante Arrhenius, who reviewed this quest in his 1909 book *The Life of the Universe as Conceived by Man from the Earliest Ages to the Present Time*.

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This book is dedicated to the memory of the founders of biosemiotics, including Jakob von Uexküll, Thomas Sebeok, Gregory Bateson, and Jesper Hoffmeyer. We gratefully remember Alexander Levich, the founder of the Theoretical Biology research group at Moscow State University, where our scientific interests have been formed.

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Preface

A century ago, in the 1920s, Jakob von Uexküll discovered a new and very unusual aspect of nature, which later took shape in a new scientific discipline—biosemiotics. He demonstrated that signs and meanings exist not only in human minds and texts, but also in various living organisms that arose and have existed long before the first humans appeared. In the 1960s, Howard Pattee, Allen Newell and Herbert Simon independently rediscovered the existence of meaning in the activity of living organisms as well as in artificial intelligence agents. At the same time, the value of Uexküll's ideas had been acknowledged by the English-speaking scientific community, including by Thomas Sebeok and Gregory Bateson. Furthermore, over the last half of the century, biosemiotics has been developing intensively, and achieving interesting and significant results. However, it still has a long way to go, and this book was conceived as the next important step on this path.

The chapter authors of this book consider the origin and evolution of signs and meanings in various natural and artificial systems from different angles. Meaning is often defined as a *signified* associated in language with a signifier in the sense of Ferdinand de Saussure, or *semantics* in the sense of Charles Morris. In communication theory, meaning is the content and value of messages or information. In biosemiotics, signs and meanings are considered in a much wider sense than in linguistics, and include non-mental signification. A biosemiotic sign is a tool that thanks to its form rather than matter or energy prompts an agent (e.g., organism, cell, or protein) to perform some *meaningful* activity or change, which tends to be beneficial to the agent itself and/or associated agents (progeny, superagents). Such activity or change in response to a sign is equivalent to what biologists call *adaptation*. For example, cold temperature makes the skin of mammals grow a thicker fur, which protects an animal from cold. Besides semantics (the type of activity or change), adaptation includes a utility component, which belongs to *pragmatics* in the sense of Charles Morris. Semantics and pragmatics are two necessary and interdependent components of meanings, although in some cases we focus on either semantics or pragmatics separately. Note that syntax, one of the three components of semiotics according to Morris, is not a part of meaning, although syntax of a message (or other sign) affects its meaning.

All semiotic agents can perform meaningful actions by interpreting signs but not all of them can acquire new meanings (e.g., a ribosome). Meaning is not a material component of an agent, but rather a dynamic organization or form that supports a capacity (or affordance) of an agent to act adaptively and robustly in changing environments. Meaning can be encoded, for example, in a computer algorithm or in a text and get transferred in such a frozen state to other agents.

Biosemiotics assumes that meanings exist only in living systems, but to explain the origin of life equipped with some primordial meanings it is necessary to consider precursor

conditions in non-living systems that can be interpreted as *potential meanings*. For example, Howard Pattee envisioned that life originated from “primitive geochemical matter cycles,” where “it is the constraints of the primeval ecosystem which, in effect, generate the language in which the first specific messages can make evolutionary sense.”¹ In fact, many causal relationships can be interpreted as potential meanings. For example, the birth of a star is caused by the ignition of a thermonuclear reaction, and thus, the appearance of a star means that a thermonuclear reaction began there. The cause of the event of a new star’s appearance is simultaneously its meaning in relation to a hypothetical observer (e.g., a human astrophysicist). Such meanings exist in potential (i.e., unmanifested) form until competent agents appear who recognize their utility.

John Deely² discussed a similar example, where a fossilized bone underground is a sign of a dinosaur even if it is not observed. This sign, however, does not signify, and thus, to avoid confusion, we call it a “potential sign.” Living organisms can get additional affordances by converting potential signs into actual form and integrating new meanings into their *Umwelten* (subjective worlds). Analysis of potential signs allows us to explore adjacent possible meanings that have not been actualized yet. It does not imply pansemiosis or panpsychism because potential signs do not signify unless they are sensed and interpreted by semiotic agents.

The emergence of living organisms and their spread in the Universe led to the transformation of some potential meanings into a manifested form, in other words, to their actualization. However, the actualization of potential meanings occurs only in certain kinds of organisms that can utilize these meanings. For example, the actual position of the sun in the sky does not matter to many plants and animals,³ but it makes sense for a sunflower that turns its inflorescence to follow it. In this way, the sun plays the role of a sign for a sunflower, which interprets it as a spatial direction to follow. Expected benefits from turning to the sun include attracting pollinators (bees and flies), evaporating water on seeds which prevents fungal infection, and better photosynthesis. The more complex an organism is, the more actualized meanings it has, and the more complex connections established between these meanings become. The most highly organized animals, and especially humans, have an extremely complex organization of signs and meanings. Their appearance as a result of evolution led to the emergence of more and more complex systems of reflexes and, finally, to consciousness characterized by active learning and self-awareness.

Currently, there is no consensus on the relation between sign properties and meanings. Many molecular biologists believe that heritable features of organisms are meanings encoded in the sequence of nucleic acids in living cells. Similarly, the structuralist school in linguistics assumes that meanings are embedded in the relational structure of human language. The opposite view of the interpretational school of semiotics assumes that meanings emerge via interpretation processes, and in this respect, they do not necessarily depend on the properties of sign vehicles (i.e., material carriers of signs). The extreme version of this

¹ Pattee, H.H. (1969), How does a molecule become a message? *Developmental Biology Supplement* 3, 1-16.

² Deely, J. (1992), Semiotics and biosemiotics: Are sign-science and life-science coextensive? In: *Biosemiotics. The semiotic web 1991*. T.A. Sebeok and J. Umiker-Sebeok, (eds.) Mouton de Gruyter, New York: 45-75.

³ However, the presence of sun is essential for all photosynthetic plants and most animals with diurnal activity, and the length of the day (photoperiod) is an important cue that is used by many animals and plants to regulate metabolism, physiology, development, and reproduction.

view is unlimited relativism, where anything can be a sign of anything else for some agent. These two approaches are often combined, as in the theory of Peirce, who considered the meaning of symbols as conventional in contrast to the meaning of icons and indexes that depend on the features or correlations of sign vehicles.

We approach the dualism of structural vs. interpretational meaning from the position of the theory of semiotic agency. Semiotic agents are organisms, cells, autonomous cell components, families, colonies, species, ecological consortia, human organizations, nations, and autonomous human artifacts. Agents perform their functions via semiotic processes, such as sensing and interpretation of signs, as actions or representations, production and manipulation of signs, and/or communication (exchange of signs between interacting agents and subagents). The structural approach to meanings is most relevant for production and manipulation of signs by agents because it results in a construction of sign vehicles that somehow represent pre-existing meanings for certain agents, whereas the interpretational approach is most relevant for categorization and learning, where meanings are inferred from sign vehicles by agents in the context of their memory and the environment. Obviously, communication requires both approaches: structural and interpretational.

An important aspect of semiosis is semiogenesis, which is the emergence of new meanings. It can be either spontaneous or triggered by external or internal disturbance (e.g., mutations). New meanings are established as a result of the repeated interpretational activities (including misinterpretation) of agents in their adaptive evolution, development, and behavior. Mutations are not primary causes of evolutionary novelties, but some mutations are interpreted creatively by cells and/or their subagents based on their innate competence acquired in preceding evolution. Some adaptations emerge due to physiological and behavioral plasticity and are then stabilized by genetic accommodation. In cognitive animals and humans, new meanings emerge mostly by learning of new behaviors, concepts, and models of the world.

This book will be of interest not only to biosemioticians, but also to specialists in the evolution of signs and matter, philosophers studying the dialectics of potential and actual, as well as to anyone interested in the role of the observer and agency in biology and other natural sciences (including physics) and the origin and evolution of the Universe as a whole.

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Part I

THE NATURE OF MEANING AND ITS COMPONENTS

Introduction: Towards Integrating Studies of Meanings with Science

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<https://www.researchgate.net/profile/Alexei-Sharov>

<http://alexei.nfshost.com>

1.1 Crossing the Great Paradigm Divide

Human knowledge is deeply divided into natural sciences that pursue mechanisms and their modeling, and the humanities that are focused on meaning, value, communication, and interpretation. This book is conceived as a dialogue between interdisciplinary scholars on how to cross this *great paradigm divide* and contribute to integration of natural sciences with semiotics, a theory of meaning-making and signification, also known as *semiosis*. Developments in biology clearly indicate that semiosis is not limited to humans or vertebrate animals, but exists in all living organisms [1.3] [1.38], and this fact inspired integration of biology and semiotics into biosemiotics. In order to function and survive, all organisms strive to capture the meaning of their environments and their own activities. According to the theory of meaning proposed by Jakob von Uexküll [1.80], animals develop species-specific models of their environment (umwelten) that link environmental cues with living functions. An elementary unit of such a model is a functional circle that includes sensing, perception, and action, all integrated into a self-sustaining loop [1.78] [1.79]. This introduction chapter overviews other chapters of the book in light of major concepts of biosemiotics.

Terminology is one of the challenges in studying meanings because biosemiotics has to overcome the anthropocentric nature of all terms related to signs, meanings, agency, mind, consciousness, communication, learning, and knowledge. There is no easy solution because if the meaning of terms is expanded to all living organisms, then the differences between types of semiosis in various taxonomic groups can be lost. An alternative strategy of using parallel sets of terms for each taxonomic group is also problematic because

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such terminology would be awkward for broad evolutionary studies. Another problem with terms is related to the difference between the first-person experience (i.e., in object agent) and third-person experience (i.e., in meta-agent) [1.76]. For example, a human researcher (meta-agent), considers glucose molecules as signs that can be perceived by bacteria searching for metabolic resources. But a bacterium (object agent) does not “know” that glucose exists outside; it simply responds to incoming signals from chemoreceptors and changes its activity according to its inherited program [1.70]. Biosemiotics certainly needs a set of generic terms applicable to all organisms and its subagents, and it can be based only on meta-agent understanding. Such a set includes “sign,” “interpretation,” “semiosis,” and “agency” [1.38]. The range of application of other terms, for example, “meaning,” “mind,” “consciousness,” and “learning,” is still debated and there is no consensus.

Donald Favareau and Kalevi Kull [1.21] present a historical overview of how signs and meanings are conceptualized in the natural sciences. Ancient studies of signs mostly considered conditions when evident facts can be used to predict the non-evident, and then used to guide human actions to change the outcome (e.g., cure a patient or succeed in other goal-directed activity). One of the early achievements was recognition of deep contextuality of any predictions by Sextus Empiricus (2-3rd century), a supporter of the school of Pyrrhonian skepticism. He assumed that objects change with time and in response to various factors; and human impressions of objects depend on position, activity, and beliefs. Hence, judgments need to be suspended until the validity of induction is carefully verified. Notably, Sextus disagreed with the notion that knowledge is not achievable, which was a typical belief (according to his writings) in the school of Academic skepticism of that time.

The great paradigm divide emerged during the age of Enlightenment (17–18th centuries), when the whole domain of science was restructured to eliminate any cognitive elements (*res cogitans*) and focus on intrinsic properties of things (*res extensa*), which were assumed fully objective and verifiable. This worldview was typical for physics and chemistry, but it also influenced the development of biology and supported mechanistic mentality and the heuristic of reductionism. However, the need for the theory of signs and meanings reemerged in the contemporary science and resulted in the development of semiotics theories that were initially associated with the humanities (i.e., philosophy, linguistics, and psychology), but recently spread to biology, cybernetics, and other sciences. Favareau and Kull [1.21] describe in detail the general semiotic theory and its further development in biosemiotics, which has advanced in formulating such terms as sign, interpretation, semiotic agency, umwelt, semiosphere, scaffolding, and habit. In contrast to the mechanistic metaphor of computation, biosemiotics considers *semiotic modeling* which is embodied, anticipatory, and supported by a hierarchy of meanings. Favareau and Kull pay special attention to the problem of *semiotic realism* presented as a middle path between radical skepticism and naïve realism. They follow Peirce’s notions of pragmatic maxim and final interpretant “toward which *the actual* tends” [1.54], CP 5.312, as guiding principles. In conclusion, “it is thus through signs that we are *more fully joined* to the world” [1.21] (*italics original*).

Bashir Ahmad and Richard Gordon [1.1] show that the old reductionist heuristic in science, stating that higher-level phenomena can be reduced to the processes occurring at lower levels, fails as physical reality is studied at progressively smaller scales and “the burden of proof on smaller entities became ever larger.” The problem is not limited to the immense combinatorial complexity of combinations at the lower level, but in addition, higher-level emergent phenomena actually change what happens at a lower level. Examples

of top-down causation are most numerous in living systems, where catalytic biomolecules enable chemical reactions and quantum effects that never occur in the non-living nature. Ahmad and Gordon present numerous examples of such non-reductionist effects in physics that include the second law of thermodynamics (increasing of entropy), rounding of liquid drops, percolation, gravity, and superconductivity. Following Arthur Koestler [1.36], they argue that each hierarchical level has its own rules of operation and these rules have bi-directional effects on both lower and higher levels; thus, physics is not reductionist and the world needs to be explained by Janus-faced¹ hierarchies.

The theories of information [1.62] and cybernetics [1.83] were thought to provide a link between natural sciences and human communication, but the term “information” is interpreted differently on each side of the paradigm divide. Terrence Deacon [1.18], p. 71, describes the difference:

At one extreme, abstraction of the formal concept of information from its referential and normative properties in everyday use and in the many areas of natural science—such as biology and cognitive neuroscience, where these nonquantifiable properties are relevant—has led to generations of efforts to formally incorporate these properties, but without widespread acceptance. At the other extreme, semiotic theories, which take issues of reference and interpretation as their focus, have largely remained confined to discussions in the humanities and social sciences, and efforts to formalize these theories have also gained limited widespread acceptance.

Deacon further explains that physicists and engineers are interested in the transmission of information no matter what it means for the end user. In contrast, biology and psychology analyze information in the context of function and reference, and linguists are interested in symbolic relations between words and their meanings. To integrate these aspects of information, Deacon turns to the semiotic theory of Charles Morris, who distinguished syntax, semantics and pragmatics as three aspects of semiosis. Deacon generalizes these aspects to make them applicable beyond human language and describes them as “*medium or signal properties* (with syntax as a special case), *referential properties* (with meaning as a special case), and *normative or functional properties* (with pragmatics as a special case)” [1.18], p. 75. In simple cases (e.g., in icons and indexes), interpretation is mediated by medium/signal properties and yields referential properties. But symbols require additional conventional and socially shared rules that integrate all three levels of semiosis.

Deacon addresses the problem of semiotic grounding, which “is the property of ‘aboutness,’ the non-intrinsicality of reference” [1.18], p. 77. He argues that “[s]ign vehicle properties don’t therefore determine reference, instead they serve as *affordances* that aid the interpretation process.” The two major classes of such affordances are: “(i) shared formal properties between sign vehicle and object (iconicity), and (ii) some physical-temporal correlation or contiguity between sign vehicle and the object of reference (indexicality).” In contrast, symbolic reference is not linked on the features of a sign vehicle but instead relies on “a kind of iconicity between different interpretive habits in a community of symbol users” (ibid., p. 79).

To develop a unified approach to the studies of physical, biological and social systems, Anton Sukhoverkhov and Arran Gare [1.73] delineate three domains of information

¹ Janus is a two-faced Roman god, associated with beginnings and entrance-exit opposition.

(or “memory”) in the universe: physical, biological, and social.² Following Nöth and Deely, they consider physical “virtual signs” that carry information about past events no matter if they are observed or not. These signs constitute *physical memory* that can be used to reconstruct the past or make prediction of the future. At the second level, *biological memory* connects physical reality with internally represented reality, such as objects or mental associations. Finally, the third level is represented by *social memory* that stores collective experience in symbols, myths, inferences (e.g., causation models), and social activity. Social memory and language supports modeling functions such as production of resources and dwelling structures. This conceptual framework is then applied to describe the origin and evolution of human language.

A similar monistic approach to meaning is proposed by George Mikhailovsky [1.46], who considers a hierarchy of meanings that integrates the physical world, living organisms, cognition, and the noosphere of human social systems. In the physical world, meanings take the form of symptoms (meaning-in-itself) that potentially can be interpreted by organisms. In organisms, meanings represent intentions that connect perception with action; and in human language, meanings are expressed in words and other symbols. The qualitative changes of systems occur via adding new levels of hierarchy, a process called *hierarchogenesis*. Mikhailovsky describes 15 hierarchogenic steps in the evolution of the world, which are further grouped into cosmic (six steps from quark-gluon plasma to galaxies) and substantive (nine steps from heteroatomic molecules to noosphere) branches. The latter branch includes the origin of life, prokaryotic cells, eukaryotic cells, multicellular organisms, agroecosystems, and nations/states. Qualitative steps in the evolution of meanings includes actualization of potential meanings, the rise of judgments, paradigms, and worldviews. These two components of evolution (substance and semantics) show a tendency of conversion, especially since the end of the last century.

Mikhailovsky then introduces the new term “eventity”—a shorthand for “evolving entity” which can be represented by a sequence of events constituting its evolution.³ Meanings exist only in eventities, since any meaning presupposes conditioning either by a preceding (causality) or a consequent (purposiveness) event. Abiotic eventities, such as stars, contain only potential meanings, while living eventities (agents) can actualize the meanings of other eventities as well as their own. Mikhailovsky identifies a nine-level structural semantic hierarchy of living eventities consisting of three triplets (“word” – “text” – “phrase”) for several hierarchical steps of general evolution. In addition, he delineates the behavioral semantic hierarchy of living beings spanning from elementary meanings through judgments and paradigms to complex worldviews. The first two belong to biosemiotics, and the last two are unique to humans. In this way, both types of semantic hierarchy are intertwined with several later steps of general hierarchogenesis.

In contrast to Sukhoverkhov, Gare, and Mikhailovsky, who assume that meaning or information exists even in the physical world without life, Alexei Sharov [1.68] takes a biosemiotic approach to the ontology of meanings, according to which meanings exist only due to their relation with interpreters: living organisms and life-dependent semiotic agents. The latter category of agents includes ribosomes and functional proteins in living cells, and

² The last two domains are represented by life and human civilization on Earth and by hypothetical biospheres and civilizations on exoplanets.

³ A similar term is “occurrent,” which is used by Caetano-Anollés [1.13].

autonomous human artifacts (computers and robots). However, according to Sharov, the relation between meanings and interpreters can be actual or potential, and thus, *actual meanings* are those that are currently interpreted by semiotic agents, whereas *potential meanings* are those that are interpretable (i.e., knowable) by some agents, which are currently either not present or not active. In physics, potentiality is described as a field that can be measured at any point in space by an appropriate device. Sharov proposes that potential meaning can be similarly presented as a *semiotic field* measurable by some competent semiotic agent if it is placed near the meaning carrier. Natural resources are potential meanings that existed long before the origin of life, but they are recognized as “potential meanings” only retrospectively, after the emergence of organisms capable of sensing and using these resources for their own benefit. Sharov wrote:

Such ontology of meanings is agency-dependent, similar to radical constructivism [1.77], but in addition, meanings are pragmatic and become corrected through repetition of the corresponding functional cycle. It is initially subjective but can spread via interaction and communication and become objective within the community of agents. Such collective knowledge is updated with the emergence of each new kind of agency: first, actual meanings are updated in space and time proximity of these new agents, and second, potential meanings are updated in the whole universe, as well as in the reconstructed past, and in the projected future [1.68], p. 150.

Alexander Kravchenko [1.37] develops the ontology of meanings starting from principles of radical constructivism, which “highlights the crucial role of the observer in constructing a universe as ‘objectivity in parentheses.’” However, the theory of constructivism is traditionally applied to humans and therefore it is inherently anthropocentric. To overcome this limitation, Kravchenko extends this approach to non-human organisms, which, according to biosemiotics, are capable of perception and purposeful behavior. Also, in contrast to radical constructivism which treats meanings as artificial constructs, Kravchenko considers meaning as a “value-based relationship between the organism and its world of experience,” following Zlatev [1.85]. In other words, meaning integrates the observer and the observed in the process of normative-controlled iterative interaction. In the case of humans, these relationships are encoded in language, and thus, meanings cannot be fully separated from the historically developed word use:

Much, if not all, of what we think we, as observers, know about the world, is the result of our operations of distinction we make in language, or naming – specification of an entity by operationally cleaving it from a background. Once such a distinction is made, a thing with the properties that the operation of distinction specifies is added to the enlanguaged world. [...] and there are as many realities as there are observers [1.37], p. 171.

Kravchenko notes that the actual and potential are ontologically different, although in language we claim both of them as “existing.” In this respect, “‘past’ and ‘future’ are mental constructs that *belong to the present* just as any other act of thinking” [1.37] (*italics mine*). However, in contrast to biosemiotics tradition, he rejects using the notion of “sign” from the position of a third-person observer. As a result, he proposes to apply this notion only if an organism can categorize a thing as a “sign.” In particular, Kravchenko disagrees with Maritain [1.44], p. 53, that all animals “make use of signs without perceiving the relation of signification.”

1.2 What is Meaning?

Meanings or ideas are generally considered as *components of mind* that comprise human understanding and knowledge [1.39], Book II, chapters I, XII. These components are brought to our attention by sensing, perception, reflection, contemplation, and by interpreting words and other language units. In linguistics, meaning appears as a *signified* associated with a *signifier*, which is a sound pattern of a word [1.17]. Gottlob Frege noticed that meanings, besides being mental components, also refer to objects in the real world. Thus, he distinguished two aspects of meaning: *reference* and *sense* [1.23], a dichotomy that is similar to opposing of *object* and *concept*. Then, Charles Peirce proposed a triadic sign relation: “I define a sign as anything which is so determined by something else, called its Object, and so determines an effect upon a person, which effect I call its interpretant, that the later is thereby mediately determined by the former” [1.55], EP2.478. One contemporary understanding of Peirce’s sign is that object is akin to a signified or reference, and interpretant is a relation between the sign vehicle and its object [1.4]. In other words, the object and interpretant are two aspects of meaning communicated by the sign. Peirce assumed that sign relations are grounded in transcendental logic, and thus, they can be non-human and even non-mental. Hence, he applied it to habits of animals and plants (e.g., sunflower [1.54], CP 2.274).

But if meaning is not necessarily mental, then what is it? The authors of this book propose different answers. Favareau and Kull [1.21], p. 28, assume “that ‘meaning’ is always and everywhere, a function of sign relationships,” understood as Peirce’s triadic relations and functional circles of von Uexküll [1.80]. In other words, meaning integrates a knower (semiotic agent) with something known. Mikhailovsky considers meaning as a “component of the world that takes the form of indicator or symptom in the non-living world, intention of organism action, or something expressed in words or other symbols [in human language]” [1.46], p. 101.

According to Sharov [1.68], p. 137, “meaningful things, processes, or relations are those that have significance for organisms as indicated by either behavioral choice or regulation of innate habits and processes.” Some meanings are intrinsic to non-living things (e.g., gravity, chemical valence, or catalysis); they exist in a potential form until discovered by agents, and then turn into actual meanings, as they gain agent-related normativity. Other meanings are products of evolution or learning, which are established by agents for their specific purposes. Neo-Darwinism reduces significance to a single variable—fitness (a combination of survival and reproduction rates). However, Caetano-Anollés [1.13] discusses additional dimensions of significance: economy (e.g., efficiency of metabolic reactions), mechanisms that support flexibility of function and behavior (umwelt), and robustness (e.g., preparedness for unperceived and unknown). According to Sharov [1.68], meanings outlive their carrier-organisms because due to semiosis, meanings are transferred among agents and overcome the limitations of individual matter-energy systems: “meanings once actualized keep existing and evolving.”

Abir Igamberdiev [1.32], p. 266, connects meaning with final causation: “Meaning in the action of agent refers to the Aristotelian final cause, which, in his views, retrocausally directs the development of the system shaped by the material, the efficient, and the formal causes.” He applies this notion to three levels of agency organization: autopoietic closure, evolution, and social systems. The normative nature of meaning is also recognized by Kobus Marais