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SPACE, TIME, AND LIFE

THE PROBABILISTIC PATHWAYS OF EVOLUTION

V. V. NALIMOV

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Foreword

Nature geometrizeth and observeth order in all things.

—Thomas Brown

For the principle of Lagrange, the principle of virtual work, is the key to physiological equilibrium, and physiology itself has been called a problem in Maxima and Minima.

—D'Arcy Thompson, *On Growth and Form*

That Nature keeps some of her secrets longer than others—that she tells the secret of the rainbow and hides that of the Northern Lights—is a lesson taught me when I was a boy.

—D'Arcy Thompson

All science as it grows towards perfection becomes mathematical in its ideas.

—A. N. Whitehead

On islands in that sun-drenched Aegean Sea where Pythagoras had heard the music of the spheres, other curious Greeks observed that sea shells and fish skeletons were embedded high in the rocky mountains. From these facts they inferred that life had originated in the sea and had later *adapted* itself to existence on land. They included man in this great process of transformation. In other parts of the Hellenic world, Democritus postulated a cosmos composed of atoms in motion and Heraclitus posited a cosmos governed by a dialectical flux of becoming.

Such was the dawn of science in the sixth and fifth centuries before the Christian era.

It was one of the tragedies of the history of science that when Aristotle created his *World System*, he rejected atomism and mathematics as explanatory ingredients in the study of the world of living creatures. Twenty-three centuries were to pass before Pasteur found the link between geometry and the living world and D'Arcy Wentworth Thompson, a creative mathematician and expert biologist, began to put together some, but not all, of the elements of the Ionian vision of the living world.

V. V. Nalimov, emerging from the tradition of Oparin, Vernadsky, and Kolmogorov, and conscious heir also of the Hellenic pioneers, brings to this work the additional insights of a probabilistic ontology and epistemology.

The views of Nalimov have been introduced to the Western world in the trilogy already published by ISI Press: *In the Labyrinths of Language: A Mathematician's Journey*, 1981; *Faces of Science*, 1982; *Realms of The Unconscious: The Enchanted Frontier*, 1982. In all of the above, the author searched carefully the relics of ancient thinkers, East and West, for insights forgotten or covered up by modern Western science as this science displaced or demoted all other forms of cognitive inquiry.

The subject here is the evolutionary process—not in the narrow Darwinian or even neo-Darwinian sense—but as cosmic process in a context familiar to the old philosophers of nature *and* to contemporary cosmologists. This broadened concept of evolutionary process was articulated with elegance and beauty by Hermann Weyl two generations ago in his *Philosophy of Mathematics and Natural Science* (original German version, 1927):

> The statement that the natural laws are at the bottom not only of the more or less permanent structures occurring in nature, but also of all processes of temporal development, must be qualified by the remark that chance factors are never missing in a concrete development. Classical physics considers the initial state as accidental. Thus "common origin" may serve to explain features that do not follow from the laws of nature alone. Statistical thermodynamics combined with quantum physics grants chance a much wider scope but shows at the same time how chance is by no means incompatible with "almost" perfect macroscopic regularity of phenomena. Evolution is not the foundation but the keystone in the edifice of scientific knowledge. Cosmogony deals with the evolution of the universe, geology with that of the earth and its minerals, paleontology and phylogenetics with the evolution of living organisms.
>
> As his external features betray a person's age, so are the spectral lines emitted by stars clues to their stage in life, and we have thus been enabled to write with some authenticity the "life" of a typical star. James Jeans in our day put forward a cosmogonic theory based on observation and exact computations that traces the evolution from a slow rotating gas ball over a spiral nebula to a cluster of stars like the galaxy. A century earlier Laplace had advanced his hypothesis about the birth and development of the planetary system; the fact that all planets circle around the Sun in the same direction in nearly coinciding planes points very clearly to a common origin. Lemaître has recently ventured still further back in the history of the universe than did Jeans. The decisive factor in his cosmogony is the expansive force as expressed by the cosmological term in Einstein's equations of gravitation. Under the numerical conditions assumed by Lemaître, gravitational attraction

> almost balances the expansion, so that at a certain precarious phase of evolution minute local variations of density give rise to accumulative condensations. He surmises that the world has its origin in the radioactive disintegration of a single giant atom. There is certainly much that is hypothetical and preliminary in such cosmogonies; to mention but one point: deeper insight into the basic nature of gravitation will very likely result in radical modifications. But in view of all the achievements of astrophysics, it can hardly be doubted that the chosen approach is fundamentally right, that one has to appeal to atomic physics in order to explain the inner constitution of the stars and the evolution of the stellar system.
>
> Among the three inferred evolutions mentioned above, that of the Earth is the least hypothetical. The empirical evidence by which the reconstruction of the Earth's past history is supported is by far the strongest, and the physical interpretation of the relevant geological processes is nowhere beset by difficulties of a principal character.

Read as a prophecy rather than a statement of fact, Weyl was remarkably prescient. Still to come was the biological revolution occasioned by the discovery of the structure and role of DNA, the beginning of the understanding and decoding of gene information storage, and human intervention at the very heart of the life processes. To this must be added the extraordinary expansion of geophysics, geochemistry, and the far-flung triumphs of molecular biology!

With this immense terrain in view, Nalimov focuses on two main themes: (1) the stochastic element within the process of variability, and (2) the explanatory power of the probabilistic approach. It is not to be assumed that a generalized probabilistic metaphysics (I use the last term deliberately) has come into the world easily. Modern science evolved from its seventeenth and eighteenth century cradle in the swaddling clothes of a rigorous deterministic causal structure, a structure that had metascientific support from theological and philosophical traditions that were centuries old. (Nalimov has discussed this in the previously cited works.) Probability as a guiding theory had to overcome its origins as a guide to proprietors of gambling halls and insurance companies. Only by the mid-nineteenth century did the rise of statistical mechanics clear the air and mandate a new methodology. But what an improbable coincidence it was that Gregor Mendel (1822–1884) and Ludwig Boltzmann (1844–1906) were contemporaries!

Genetics came into the world as a statistical discipline and its amazing success is proof, if any was needed, that a theory of this type is as rigorous as one derived from differential equations. This issue also is examined by Nalimov: How have the precise geometric structures known to modern biology emerged in a process that contains undeniable randomness? Is it not at least possible that Nalimov's suggestion, that the answer may come from mathematics, is correct? The Nobel Laureate in physics, Ilya Prigogine, states in his *Order Out of Chaos:*

> Our position is that the science described by Koyré is no longer our science. Not because we are concerned with new unimaginable objects closer to magic than to logic, but because as scientists we are beginning to go beyond what Koyré called "the world of quantity" into the world of "qualities" and thus of "becoming."

and L. C. Whyte long ago wrote in *The Next Development of Man:*

> Man finds himself in the universal process, by finding the universal process within himself. Tension continues, but henceforward his struggle is with, not against the processes of nature.

To indicate how closely some of Nalimov's ideas developed in this essay—particularly those concerned with space, time, and spontaneity—converge towards those on the frontiers of contemporary cosmology, we turn again to the beautiful work of Prigogine:

> For a long time, however, physicists thought they could define the inert structure of crystals as the only physical order that is predictable and reproducible and approach equilibrium as the only evolution that could be deduced from the fundamental laws of physics. Thus any attempt at extrapolation from thermodynamic descriptions was to define as rare and unpredictable the kind of evolution described by biology and the social sciences. How, for example, could Darwinian evolution—the statistical *selection* of rare events—be reconciled with the statistical disappearance of all peculiarities, of all rare configurations, described by Boltzmann? As Roger Caillois asks: "Can Carnot and Darwin both be right?"
>
> It is interesting to note how similar in essence the Darwinian approach is to the path explored by Boltzmann. This may be more than a coincidence. We know that Boltzmann had immense admiration for Darwin. Darwin's theory begins with an assumption of the spontaneous fluctuations of species: then selection leads to irreversible biological evolution. Therefore, as with Boltzmann, a randomness leads to irreversibility. Yet the result is very different. Boltzmann's interpretation implies the forgetting of initial conditions, the "destruction" of initial structures, while Darwinian evolution is associated with self-organization, ever-increasing complexity.
>
> To sum up our argument so far, equilibrium thermodynamics was the first response of physics to the problem of nature's complexity. This response was expressed in terms of the dissipation of energy, the forgetting of initial conditions, and evolution toward disorder. Classical dynamics, the science of eternal, reversible trajectories, was alien to the

> problems facing the nineteenth century, which was dominated by the concept of evolution. Equilibrium thermodynamics was in a position to oppose its view of time to that of other sciences: for thermodynamics, time implies degradation and death. As we have seen, Diderot had already asked the question: Where do we, organized beings endowed with sensations, fit in an inert world subject to dynamics? There is another question, which has plagued us for more than a century: What significance does the evolution of a living being have in the world described by thermodynamics, a world of ever-increasing disorder? What is the relationship between thermodynamic time, a time headed toward equilibrium, and the time in which evolution toward increasing complexity is occurring?
>
> Was Bergson right? Is time the very medium of innovation, or is it nothing at all?

I would end this Foreword on a personal note. During the preparation of this volume, I informed my Moscow colleague that some of his ideas might receive a hostile reception in a milieu dominated by positivism and a negative attitude to metaphysics. Only toward the end of these labors did I more clearly realize that in science and philosophy, we argue not only with our contemporaries and ancestors, but also with our descendants. Francis Bacon, "the man who saw through time," said it better than I can when in his Fourth Aphorism he said:

> The universe is not to be narrowed down to the limits of the understanding. . . , but the understanding must be stretched and enlarged to fill in the image of the universe as it is discovered."

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Preface

Comprehension of the World consists in comprehending its meanings in the constant process of their revelation. The probabilistically oriented philosophy I have developed makes it possible to construct a model that interprets the World through measure and geometry. To be in the World seems to mean to be manifested by a measure. And to be manifested is to exist in the stream of spontaneity. Spontaneity is turned to geometry on which the meanings are given perennially that exist (in a latent state) in non-existence. Spontaneity becomes the fundamental principle of life, its creative element.

The present work focuses on the living World, i.e., the World of living things. It begins with an attempt to consider the role of number in the arrangement of the living World. The subject, however, seems to be yet unprepared for its all-round comprehension. One thing is clear, though: in the living World, the part played by number is essentially different from that in the physical World. And so we pass from number taken in its concrete value to a measure. This has made it possible to describe the changeability of the living World by means of probabilistic spaces, which led to a non-trivial interpretation of the idea of creative evolutionism that may be opposed to the concept of evolution as random process.

Abstract geometric interpretation of the living World is, certainly, far from being new. Among the people who have tackled the problem are Rashevsky, Rosen, Waddington, and Thom. And I am sure the future will witness more attempts in this direction. This trend is especially stimulated by the geometrization of physics of which we are now well aware. Will any of these attempts acquire the interpretative power that will enable it to claim the right to become an abstract–symbolic theory of the living World?

At the end of this work an attempt is made to construct a new, probabilistically oriented metaphysics founded on the conception of the World as geometry.

Some parts of my study look like a dialogue with the thinkers who previously spoke on the problem of evolutionism—the book includes a lot of quotations. At the same time I am not trying to consider all the aspects of the problem of changeability. Such a review would have been cumbersome and clumsy. I should have touched on the philosophical aspects of evolutionism, its mathematical models, and its biological, culturological, linguistic and cosmogonic interpretations.

It will not be an exaggeration to assert that the modern *Weltanschauung,* no matter how it is oriented, is unavoidably linked with the understanding of the idea of evolutionism. However, it still remains unclear whether a single approach is possible here which would satisfy the representatives of various branches of modern intellectualism. The problem of evolutionism occupies a central position in my three latest books of a philosophical nature. The first of them, *In the Labyrinths of Language: A Mathematician's Journey,* shows that texts of our everyday language, in the process of being comprehended, acquire a new meaning: that is to say, their semantics undergoes an evolution. In the second book, *Faces of Science,* among many other problems, is considered that of scientific creativity, a process evolutionary in its nature. And, finally, the third book, *Realms of the Unconscious: The Enchanted Frontier,* demonstrates how meanings are revealed in the deep levels of our consciousness—this, again, is also a manifestation of evolutionism. In all instances I describe the evolutionary process through the Bayesian model to which I ascribe the status of a probabilistic–numerical syllogism. Sometimes I am criticized for attaching too much explanatory power to the Bayesian syllogism. As a matter of fact, this is not so: in the long run, it describes only the process of evolution of the text semantics, of those texts through which we view the World. In the present work I am giving an expanded picture of biological evolutionism, a subject I touched upon in *Realms of the Unconscious* (see Chapter 3).

My work based on the notion of a morphological continuum may also be regarded as a contribution to the broad discussion surrounding the book by R. Sheldrake (1981)[1] that revived the concept of morphogenetic fields. As a matter of fact, I became acquainted with his book after the present book was finished. In contrast to his views, I tried to develop my conception so that it would naturally embrace the idea of emergence of new forms.

My theme, though from a different standpoint, has also been approached by Ditfurth (1983) in his book devoted to evolution as a creative process.

I might also compare my work with a highly readable book by Bateson

[1]Note that Sheldrake's conception occupies a central position in the book by Briggs and Peat (1983) devoted to the *holistic vision of the World* in science, a new paradigm emerging in front of our eyes. Sheldrake's ideas are considered from the same viewpoint as the ideas of such scholars as Bohm, Prigogine, Pribram, and Jantsch.

(1979). His principal idea is expressed in the following words: "the biological evolution is mental process—and thinking is the evolutionary process." My conception of the nature of global evolutionism is also in accord with that formula. However, my interpretation is different, being essentially non-mechanistic. I also ascribe a different role to number (in contrast to Bateson).

Last but not least, my book may be regarded as a response to the appeal made by Capra (1983) urging us to see that we are now at the turning point: all Science, and all culture as well, should, following the evolution of modern physics, abandon the mechanistic vision of the World, whose source lies in the Cartesian–Newtonian concepts.

The philosophical comprehension of the problem of evolutionism does not lose its intensity. The publications devoted to it flood into many directions. Will they flow into one riverbed?

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This is my fourth book issued in English by ISI Press, and I would like to express my deep gratitude to my friends who have made it possible. I am very grateful to Robert A. Day, Director of ISI Press, for a very accurate and quick edition of the books and for their brilliant polygraphic quality. I am deeply indebted to Dr. Eugene Garfield, President of the Institute for Scientific Information. I have long been connected with him by friendship and the ideas that we share in science-of-science. Dr. Garfield has made an important contribution by crossing the gap between Russian and American scientific and scientific–philosophical thought. He has also sent me many books that gave me the opportunity to be in touch with modern American scientific thought. He not only made possible the publication of my books, but in his articles also drew the attention of American readers to them. And, last but not least, my thanks are due to Professor Robert Colodny of the University of Pittsburgh, who was the permanent editor of all my books issued by ISI Press. He meticulously corrected the uneven style and sometimes blunders of the translation and never failed to draw my attention to the necessity of thoroughly coordinating my ideas with the American intellectual tradition. I regularly receive from Professor Colodny books, issues of scientific journals, and even clippings and photocopies of separate pages. All that has enabled me to orient myself within the flow of sometimes distant ideas. I can't help being amazed by the scope of information Professor Colodny has the mastery of as well as by his profound scientific and philosophical concepts. His personality is, indeed, encyclopedic.

And I leave the space

Entering the desolated garden of values
And breaking through the imaginary constancy
And self-consistency of causes.
And your manual, oh infinity,
I am reading alone, without people,—
The leafless wild healer-book,
The math-book of immense roots.

O. Mandelshtam, 1933

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Chapter 1

Number as a Symbol

World as a Text Structured by Rhythm

No matter what you are, a scholar, a poet, or an unprejudiced observer peering into the surrounding world, you search there for clarity, order, and harmony. We regard the world as a text. We interact with the World through the texts accessible to our consciousness. Looking into the depths of our consciousness, we start to regard ourselves as a text. We begin to comprehend the metaphor by Heidegger-Ricouer: *Man is a language* (see the Preface by the editor to Ricouer, 1974).

The unity of the World finds its expression in the *language* of its texts linking all the individual manifestations of life with the unique, semantic fundamental principal of the World. Here again we have much in common with Heidegger's hermeneutic philosophy: his epistemology proceeds from the concept of the World as a specific ontologized text (Wilson, 1981). My wish is to deepen the vision of the World as a language, proceeding from the idea that the perennial semantics is unpacked into a text through number.

The texts of the physical World are revealed to us as a numerical arrangement of things in time and space. An elementary particle, an atom, the solar system, the galaxy—all of them are now viewed as hierarchies of rhythmically organized processes. A crystal is rhythm imprinted in a stone. The law by Titius-Bode on the geometric progression in the interplanetary distances represents rhythm imprinted in the cosmic space (Nieto, 1972). Humans also exist as the interaction of their rhythms—that of breathing, of day and night, of metabolic process, of the lunar cycles affecting feminine organisms. Soft poetic communication with nature is, in fact, interaction of the personal rhythm with the rhythm of the World. Carlos Castaneda, author of a series of books written in a specific and unusual manner (a pantheistic view of the World is revealed in the process of apprenticeship of an anthropologist, a man of the Western world, taught by a sorcerer, an outstanding representative of the ancient Mexican culture) describes the experience of direct contact with nature:

> They whispered in my ears until I again had the sensation that I had been split into two. I became a mist, like the day before, a yellow glow that sensed everything directly. That is, I could "know" things. There were no thoughts involved; there were only certainties. And when I came into contact with a soft, spongy, bouncy feeling, which was outside of me and yet was part of me, I "knew" it was a tree. I sensed it was a tree by its odor. It did not smell like any specific tree I could remember, nonetheless something in me "knew" that that peculiar odor was the "essence" of tree. I did not have just the feeling that I knew, nor did I reason my knowledge out, or shuffle clues around. I simply knew that there was something there in contact with me, all around me, a friendly, warm, compelling smell emanating from something which was neither solid nor liquid but an undefined something else, which I "knew" was a tree. I felt that by "knowing" it in that manner I was tapping its essence. I was not repelled by it. It rather invited me to melt with it. It engulfed me or I engulfed it. There was a bond between us which was neither exquisite nor displeasing. (Castenada, 1974, p. 200)

He gives a poetic description of a peculiar state which we call ecstasy. It is produced by the feeling of merging with the object by acquiring common breathing, common rhythm with it. Perhaps our modern art, especially music, is directed at revealing the similar faculties of people overburdened by a conceptualized attitude toward existence.

Rhythm is a number manifested in motion or in a static variety of things arranged so that we perceive them as a frozen motion.

Rhythm is now regarded as geometry. I would like to call the reader's attention to the book by Winfree (1980) whose title seems unusual at first sight: *The Geometry of Biological Time.* It contains 290 illustrations of geometric images of time.

Numerical Vision of the World as Expressed by Ancient Thinkers

Striving to understand the nature of our fundamental notions about the World, we invariably turn to look into the Past: there all the constituents structuring our consciousness seem very explicit and free from the later layers of our sophisticated culture. I frequently mentioned the numerical vision of the World in my book *Realms of the Unconscious: The Enchanted Frontier* (Nalimov, 1982). Here I shall once more return to this subject, though a few repetitions will inevitably occur.

Pythagoras seems to have been the first thinker who began to elaborate the philosophy of number. For us his name, as well as his ideas, are largely legendary. We have a more substantial knowledge of the Pythagorean school. Historians believe that it existed for only two centuries, though its influence upon Western European thought has never been completely eliminated. The mathematization of natural sciences and the humanities which developed more recently may be linked philosophically to the ideas of the Pythagorean school.

According to Gutherie (1962), Pythagoras held the essence of all things to be abstract, of a numerical nature. Further development of Pythagoras's ideas can be found in a book by Popper and Eccles (1977). These authors, proceeding from Kahn (1974) wrote:

> The first, the initial theory, probably due to Pythagoras himself or perhaps to Philolaus the Pythagorean, was that the immortal soul of man was a harmony or attunement of abstract numbers. These numbers and their harmonious relations precede and survive the body. The second theory put by Plato in the mouth of Simmias, a pupil of Philolaus, was that the soul is a harmony or attunement of the body, like the harmony or attunement of a lyre. . . . It must perish with the body, as the harmony of the lyre must perish with the lyre. The second theory became popular, and was extensively discussed by Plato and Aristotle. The popularity was clearly due to the fact that it offered an easily grasped model of mind-body interaction. (p. 164)

It is only natural that we consider the first of the two theories ascribed to Pythagoras the most interesting. Not being explained, it contains an enchanting meaning already in its enigmatic formulation. The famous tractatus "On Numbers" by Plotinus (1956) may be regarded as an attempt to make Pythagoras's teaching explicit. However, the tractatus remained forever the most enigmatic treatise of the world's philosophical thought. It contains an extraordinary attempt to explain how by means of number *Being* gave birth to the *Multiple.* The well-known Soviet Hellenist Losev (1982) in his translation of the tractatus, primarily an interpretative effort, shows that Plotinus linked objects with *number* given as a *distribution.* Thus, the gap is overcome between the ancient teaching of the numerical principle of the World and contemporary ideas of the possibility of describing the World through the probability distribution functions. I have resorted to Plotinus's *Enneads* (1956) more than once, and one chapter in my earlier book (Nalimov, 1982) is devoted to the tractatus "On Numbers." To my mind, by elaborating probabilistically oriented philosophy, we reveal the vision of the World that had been revealed to Plotinus, though in a different form that now is difficult to grasp.

It seems that the direct successor of Plotinus was Proclus.[1] Here I

[1] Proclus (410–485) was one of the most outstanding representatives of neo-Platonism. For some time he was head of the Athenian school of neo-Platonism. His literary heritage contains several thousand pages.

quote a few excerpts from his *Elements of Theology* (1963):

1. Every manifold in some way participates in unity.
2. All that participates in unity is both one and not-one.
5. Every manifold is posterior to the One.
6. Every manifold is composed either of unified groups or of henads (units).
47. All that is self-constituted is without parts and simple.
49. All that is self-constituted is perpetual.
50. All that is measured by time either in its existence or in its activity is in a process of coming-to-be in that respect in which it is measured by time.
51. All that is self-constituted transcends the things which are measured by time in respect of their existence.
67. Every whole is either a whole-before-the-parts, a whole-of-parts, or a whole-in-the-part.
69. Every whole-of-parts participates the whole-before-the-parts.
117. Every God is a measure of things existent.
149. The entire manifold of divine henads is finite in number.
162. All those henads that illuminate true Being are secret and intelligible: secret as conjoined with the One, intelligible as participated by Being.
171. Every intelligence is an indivisible existence.

The whole text of Proclus's *Elements of Theology* is like that. We see how difficult it was for the ancient thinker to find the right words to express the idea that the World was a numerical unpacking of the Entity. Now, proceeding from the language of probabilistic concepts, I shall try to express the same idea freely and easily.

Note that both Pythagoras and the neo-Platonists regarded number in its abstract manifestation as a measure which does not take concrete numerical values. However, a brief historical analysis of the varieties of cultures will show, somewhat to our surprise, that individual numerical values always used to be treated with a specific significance. A concrete number acted as a *symbol*. It was not only and not so much the means of calculation but a sign charged with religious–philosophic semantics. A case in point is the mythological meaning ascribed to the number *eight* in many past cultures: completion; the whole; regeneration, rebirth; perfect intelligence; the order of the celestial world established on earth, etc.[2]

Another illustration: *Realms of the Unconscious* (Nalimov, 1982) contains a graph of frequencies of occurrence of words denoting numbers in the Bible (which we regard as a basic text laying the foundations for European culture). What leaps to the eye is the sharp selectivity in the use

[2]A detailed description of the mythology of the number *eight* may be found in a book by Cooper (1978); it is reproduced briefly on p. 223 of my earlier book (Nalimov, 1982).

of numbers. It can in no way be accounted for by purely statistical fluctuation since the sample was too large: the total number of words denoting numbers from 1 to 20 was 1,471.

One of the numbers of high priority is three. It is amazingly interlaced into the various manifestations of European culture. Let us try to reveal its meaning. Primarily, this is the sacral number of Christianity—recall the icon Trinity by Rublyov, one of the most outstanding relics of the past Russian Christian culture. However, *three* is in no way a specifically Christian symbol. Plotinus was not a Christian author, but in his treatises the number *three* plays the leading part[3]: the Supreme Being is given through triunity.

Still earlier, though in a less clear way, the idea of triunity had been expressed by Plato, the thinker who gave birth to Western European thought. The idea of triunity is amazingly alive in the culture of today. It structures our thinking: recall the three elements in the Aristotelian syllogism which forms the basis for our logic and *triad* in dialectics. The possibility of cause-effect description of the world is revealed through the *triad:* space, time, law. The space of our World is three-dimensional.

Why is space three-dimensional? This problem is considered in detail by Gorelik (1982), who emphasizes the role of dimensions in physics:

> It is of interest to compare the attitude of physicists to three-dimensionality as a fundamental property of space made explicit, as Ehrenfest[4] has shown, in the fundamental physical laws, with their attitude to the laws of conservation—one of the most efficient tools of theoretical physics. In some sense dimension is more fundamental than the laws of conservation. In the latter a definite structure of space-time is obviously "built-in," in particular, their symmetry and dimensions. (p. 94)

However, in the conclusion to the book we read,

> What is to be done about the question "Why is space three-dimensional?" So far physics has not given a final answer to it. (p. 154).

The author observes that, as a result of the immense role the concept of dimensions plays in physics, this question remains as important as it is enigmatic.[5]

[3]I proceed here from *Enneads* by Plotinus (1956) which includes the tractatus "On Numbers." *Enneads* (literally, "nines" in Greek) are structured by the number *three:* they consist of six parts, each of which contains nine treaties.

[4]Paul Ehrenfest (1880–1933), disciple of Boltzmann and profound theoretical physicist.

[5]We should not forget that modern physics has not removed from the agenda the problem of considering spaces of high dimensions. See, for example, the paper by Barrow (McCrea and Rees, 1983, pp. 337–347) and the popular paper by Thomsen (1984).

The space of human color perception also turns out to be three-dimensional. The number *three* pursues us in our everyday life: trilogy, tripod, triptych. Mythological heroes usually go in threes: the tri-unity Brahma, Siva, and Vishnu of Hinduism; family triplets in Roman mythology (Jupiter, Juno, and Minerva) and Roman cult (Cerera-Libera-Liber). The same is true of fiction: recall the *three* musketeers; also note the paper (Vetlovskaya, 1971) emphasizing the insistent repetition of the number "3" in *The Brothers Karamazov*. The call for the French revolution sounded as a *triad:* freedom, equality, fraternity (during the French revolution this slogan sounded as: freedom, equality, or death). Perhaps it is relevant to ask whether different countries have a different degree of preference of numerical symbols. Note that in the Bible (see Fig. 12 in Nalimov, 1982) the number *eight* does not show any prominence in the frequency of occurrence. This symbol, though preserved in European culture, remains somewhat muffled. It can be found in the architecture of temples, in its symbolic system: octagonal crosses and stars. Sometimes it starts to personify what remains in the shadow of the culture. It was Leibniz who, speculating on numbers, noticed that while *three* was a triangular number, *eight* was a cubic one charged with complicated trinity. Comprehension of this fact required a level of cultural evolution that was able to develop only from spatial-architectural symbolics.

The roots of modern Western culture lie deep in the world of the Mediterranean: at that epoch the carrier of the intellectual element was represented first of all by the Greek language. The Greek word λογος is polymorphous (Dvoretsky, 1958). Its semantic field translated into Russian is rendered first of all by the notions *word* and *speech,* but on the periphery of the field occur such concepts as *counting, calculus, number, group, category.* The term *word* in its broad meaning turns out to be synonymous to the terms *number* and *calculus.* Hence, the famous beginning of the Gospel of John might as well contain the following peripheral meaning[6]: In the beginning was Number, and Number was with God, and the Calculus was God.

Later this meaning seems to have been lost, sunk into the deep levels of consciousness: The gospels in common usage were standard translations into the modern languages that preserved only part of the polymorphous meaning (though, of course, it is impossible to imagine a Russian intellectual of the past without a knowledge of Greek). At present we seem to be able to answer the question why *word* is semantically close to *number.* The point is that the emergence of fundamental constants in physics (we shall discuss them later) are defined by the *word* through which we try to perceive the World.

[6]As suggested in my earlier book (Nalimov, 1981a), we may say that this peripheral meaning opens up only to a present-day reader whose filter of text perception $p(y \mid \mu)$ is oriented toward the numerical vision of the world.

Does it not follow from what is said above, despite the briefness of exposition, that for our consciousness, or, better, for the deep unconscious levels, it is typical to reflect the structure of both the World and our behavior in it through numerical symbolics? Do we not have the right to assert that the mathematization of knoweldge which has become obvious nowadays answers the need inherent in our consciousness during the symbolic, numerical perception of the world?

I would like to draw the reader's attention to the words by MacCulloch quoted by Papert (1979):

> When asked what question would guide his scientific life, McCulloch answered: "What is a man so made that he can understand number and what is number so made that a man can understand it?" (pp. 118–119)

Of course, those lines may be nothing more than an unconscious reminiscence of the ancient ideas of the role played by number. The apocrypha "The Wisdom of *Solomon*" reads (Metzger, 1957): God has "arranged all things by measure and numbers and weight" (11:20). The apocryphal Gospel of Philip contains the following line: "Christ is he who is measured." "Measured" means embodied by number by means of which to the variety of the whole are attached various weights in its different parts. Otherwise, for the ancient thinker, Christ is not represented by the complete Existence but only by its numeric manifestation.

All of the three quotations above sound like paradoxes, like Zen koans which should provoke human thought and imagination. They act as a hint to something very important and essential, actually: to the role of number and measure in consciousness and in the Universe and to the links between them.

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Chapter 2

Number as an Organizing Principle of the World

Number as an Organizing Principle of the Physical World

Peering into the World, we start to comprehend that its texts are seen by us in a stratification determined by their numerical structure. And each of the strata requires a specific approach to its description, especially if the latter is mathematical. A sufficiently precise demarcation line seems to pass between the physical World and the living World.

Now a few words on the numerical arrangement of the physical World. We perceive matter as it changes. But the changes occur in the World with a *stable structure*. Stability stems from the invariability of *fundamental physical constants*[1] (Rosental, 1980). The set of these constants is necessary and sufficient for the existence of our World. It has been shown that even a slight modification in one of the fundamental constants, all the rest remaining stable and all the physical laws preserved, leads to the impossibility of existence of the *basic* stable connected states: nuclei, atoms, stars, and galaxies. However, the stability of structures does not make the World unchangeable. The concept of *gravitational collapse*,

[1]The fundamental constants in physics include the speed of light, the Planck constant, the electron charge, the constant of fine structure (pure value $\alpha \simeq 1/137$), etc. By the way, a purely numerical approach to the nature of the number α^{-1} seemed quite possible for some time: the problem was whether it could be represented as a combination of prime numbers 2,3,5 and the transcendental numbers π and e or given by an algebraic equation whose coefficients are integers. Such scientists as Eddington and Born tackled the problem (Born, 1935). By now it has turned into a computer game. While the experimental value of α^{-1} is 137.03611 ± .00021, Roskies and Peres (1971) indicate, for example, the following value:

$$137.036007 = 2^{5/3}\, 3^{-8/3}\, 5^{5/2}\, \pi^{7/3},$$

$$137.03630 = 4\pi^3 + \pi^2 + \pi, \ 131d$$

which seems to be more serious than $\pi = 31^{1/3}$ (+67 ppm). The numerical analysis of mythological constants seems much more meaningful. For example, the Scheherazade number turns out to be the product of three prime, mythologically significant numbers: $1001 = 7 \times 11 \times 13$. It has a binomial looking-glass symmetry: unity, zero, zero, unity. Being sequentially raised to powers, the symmetry is preserved, and we obtain a looking-glass symmetrical pyramid (Fuller, 1975).

posing the question of the destiny of the Universe, testifies to the fact that physics now has to face a forecasting more grandiose than ever before (Misner, Thorne, and Wheeler, 1973).

> . . . the universe transforms, or transmutes, or transits, or is "reprocessed" probabilistically from one cycle of history to another in the era of collapse. . . . all the universe [. . . is . . .] from time to time "squeezed through a knot-hole," drastically "reprocessed" and started out on a fresh dynamic cycle. (p. 1214).

I shall not consider here hypothetical statements on the existence of a multitude of Universes with their own physical laws and combinations of physical constants or the idea that the Universe has gone through a multitude of cycles, at the beginning of which physical constants used to change. The important thing is that we live in the cycle characterized by the stable combination of constants[2] determining the existence of basic states. It is possible to speak about the harmony in the Universe by introducing the concept of an "expediency principle" guiding the selection of constants or even of the "biological selection of constants" (Misner, Thorne and Wheeler, 1973). Maybe our Universe is only by chance selected from the multitude of existing Universes? However, one thing is clear: our Universe, because of its structural stability, is especially suited to description by differential equations. Such a Universe arranged by means of limiting constants is viewed by us as a structure of hierarchically arranged oscillators.

Matters stand differently in the biosphere. It contains a multitude of Worlds: each large ecosystem is such a World. In contrast to the physical Universes (if they do exist in all their potential variety), those Worlds do not have clear boundaries; they interact constantly. (In physics the interaction between Universes seems to give rise to unsolvable problems.) Biological Worlds lack something analogous to physical constants, or if they do exist, they are not observable as a result of their extreme degree of fuzziness. Biology also lacks an analog for the basic connected *states*,[3] for a

[2]I direct the reader's attention to the recently published collection of papers devoted to fundamental constants (McCrea and Rees, 1983). We find there new data on the precision of constants and their stability in time. For example, the article by Smith (p. 215–219) gives the specified value of $\alpha = 1/137.035965$ and indicates that the uncertainty of estimation equals only $0.09/10^6$. Irvine (p. 239–243) describes the results of the analysis of a prehistoric natural nuclear reactor discovered at the uranium mines in Oklo, West Africa, showing that over the past 2×10^9 years the corresponding coupling constants have altered by less than one part in 10^{19}, 5×10^{17}, and 10^{12} per year.

[3]One of the manifestations of the stability of the Universe is the fact that all electrons have *identical* mass and charge. Electrons are indistinguishable. Here is an interesting remark to the point (Misner, Thorne, Wheeler, 1973):

> That an electron here has the same mass as an electron there is also a triviality or a miracle. It is a triviality in quantum electrodynamics because it is assumed rather than

biological code can hardly be called one. So if there are no stable connected *states* in the biosphere, what is there to describe by differential equations? The latter are a language convenient for description of changeability only in a structurally stable system. Making use of differential equations, we proceed from a rigid premise asserting that the World under study is so well organized that it is composed of stable structures yielding to algorithmic description. In modern physics this is no longer the World of Laplacian determinism: it may contain probabilistic phenomena, but they should not violate the fundamental stability. For example, in quantum mechanics, the ψ-function is probabilistic by its nature, but its modification is regulated by Schrödinger's differential equation containing the fundamental constant, namely, Planck's constant. The concept itself of a well-structured World cannot be defined very precisely, but it becomes explicit after juxtaposition of the physical World and the living World. Events occurring in the physical world are stretched over the numerically stable fundamental constants. This makes the world *stationary*. The living World also has its constants, but they do not rise to the rank of fundamental constants. They are non-fundamental constants,[4] such as the period of atomic half-life in physics or the temperature of melting of a metal. Their numerical values are not crucial for the existence of the World. That may well explain failures in the simulation of ecosystems by the language of differential equations (see Nalimov, 1983).

Now imagine how outraged physicists would be if they were told that they had returned to the numerical mysticism of the Pythagorean school. Perhaps, philosophers were too hasty in scorning the numerical philosophi-

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> derived. However, it is a miracle on any view that regards the universe as being from time to time "reprocessed." (p. 1215).

And what remains equally stable in the biosphere? It seems that nothing does. But it may be possible to say that in the living world the fairly limited and, therefore, stable basis is the fundamental principle which underlies everything. I quote Morowitz (1967):

> There is a ubiquitous and restricted set of small organic molecules which constitute a very large fraction of total mass of all cellular systems. This generalisation is a statement of the uniformity of biochemistry. It is one of the very significant, if infrequently discussed, results of that science. Amidst the enormous diversity of biological types including millions of recognizable species, the number of biochemical pathways is small, restricted, and ubiquitously distributed. . . . If one considers the group of low molecular weight compounds (less than 300 daltons) which can be made from carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur, this number is in the billions or higher. (pp. 47–48)

He goes on, saying that in a handbook of primary microorganism metabolites one will find only 1,313 compounds, while the list of ubiquitious compounds is much smaller and encompasses a few hundred substances.

[4]The above-mentioned collection of papers edited by McCrea and Rees (1983) contains an article by Press and Lightman (pp. 323–335) reviewing the attempts to learn the degree of dependence of our everyday life on the fundamental physical constants. The results obtained for some biological phenomena are as follows: the human size must be 3 cm; horsepower to measure human power under certain conditions equals 400 W; the velocity of a human runner touches on a record, 15 meters per second. The last two estimates are not bad. However, physical constants can hardly be said to determine the phenomena of life.

cal ideas of ancient philosophers. Maybe somewhere on the deep levels of their consciousness they anticipated the role played by number in the world order.[5] And only now their previously speculative constructions acquire scientific significance.

A skeptical reader can also pose the following question: Where is the guarantee that fundamental constants do exist? Perhaps they are but an artifact generated by the peculiarities of the language invented by physicists to describe the world? Modern physics also contains a conception (though an appendix one) called "bootstrap" which denies the existence of any fundamental concepts. The universe is viewed within this system of concepts as a dialectic web of interactions—none of its parts or properties is fundamental (Chew, 1968; Capra, 1976). In Wheeler's geometrodynamics (more on this later) the picture of the World contains interactions without interaction constants.

As far as I know, the above question is never posed by physicists, but I consider its formulation to be legitimate, and I would even answer it as follows: the World in front of our eyes is a *text*. Our interactions with the text represent a psychological translation into our human languages comprehensible to us. One of them is the language of poetry with its rhythmical arrangement. Rhythms are underlain by number. Another such language is that of modern physics: it is also organized through number, but here numbers act as constants. We do not know whether the numerical constants of the World are invariant with respect to all possible languages of physics. But even the attempt to create the "bootstrap" conception bears witness to the fact that, if it is possible at all to imagine the language of physics void of the concept of fundamental constants, we still cannot reject number: in "bootstrap" the structure of the World of subatomic particles is given by the matrix of transition probabilities.

The above speculations seem to be sufficient for making an attempt to consider the role played by number philosophically.

First, we turn to Kant, the founder of contemporary epistemology and the first philosopher who understood Newtonian science. He constructed transcendental philosophy based on the revelation of the role of *a priori* forms of consciousness. For Kant space is an *a priori* form of the outward sensuous contemplation, and time, that of inward sensuous contemplation. It is the *a priori* nature of contemplating space and time that makes them common and unconditionally necessary. The condition for the possibility of *a priori* synthetic judgments is represented by 12 categories divided into

[5]Ancient thinkers certainly tried to do something more, namely, to link their knowledge about the World with numerical values. For example, from the days of yore came the idea that the number of celestial bodies wandering among the stars is given by the sacred number *seven* (Sun, Moon, Mars, Venus, Saturn, Mercury, Jupiter). However, the earliest achievements of modern astronomers challenged these ideas. The fight against primitive knowledge rigidly fixed by numbers turned into a fight against the idea of a numerical vision of the World.

four groups:

> *quantity* includes categories of unity, multitude, and integrity
> *quality* includes reality, negation, and limitation
> *relation* includes relation between substance and property, cause and effect, interaction
> *modality* includes possibility, actuality, and necessity.

According to Kant, reason fills these categories not obtained from experience with the content which it borrowed from our sensuous perception.

Number was not included by Kant in the list of *a priori* forms of contemplation, though it determined the notions of quantity and variety (Kant, 1930).

> For the external sense of pure image of all quantities (*quantorum*) is space; the pure image of all objects of sense in general, is time. But the pure *schema* of *quantity* (*quantitatis*) as a conception of the understanding, is *number*, a representation which comprehends the successive addition of one to one (homogeneous quantities). Thus, number is nothing else than the unity of the synthesis of the manifold in a homogeneous intuition by means of my generating time itself in my apprehension of the intuition. (p. 110)

Thus, *number* produced by contemplation through time created by man seems to be more *fundamental* than Kantian *a priori* categories. Note also that Kant's mathematical constructions are of an *a priori* character.

> Before all, be it observed, that proper mathematical propositions are always judgments *a priori*, and not empirical, because they carry along with them the conception of necessity which cannot be given by experience. If this be demurred to, it matters not; I will then limit my assertion to *pure* mathematics; the very conception of which implies, that it consists of knowledge altogether non-empirical and *a priori*. (Introduction, vol. 1, pp. 9–10)

I have made this digression to philosophical classicism in order to show the place number could have occupied within the system of epistemological constructions. Number may act as a basic category of consciousness, the most fundamental one of those accessible for our comprehension. But in Western culture, the role of number happened to be concealed, buried under the cover of logical thought. Physicists discovered the crucial part of fundamental concepts only recently. Excavations are going on in other branches of knowledge.

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Zipf's Law as a Manifestation of the Numerical Arrangement of the Text

Can numerical regulations be observed in everyday language created by man? This is Zipf's law reflecting numerical regularities not only in written texts, but also in the texts of biotaxonomy,[6]

$$P_n = \frac{d}{n} \qquad (n = 1, 2, \ldots)$$

where n is the rank of words arranged according to the frequency of their occurrence, P_n is the frequency of occurrence for a word of the nth rank, and d is a constant (Zipf's law can be recorded in various modifications and is often called the Estoup-Condon-Zipf-Mandelbrot law).

At first the idea was that this law reflected numerical arrangement of the language itself. But soon various troubles came to the surface that called for a new interpretation. First of all, it turned out that the law was valid only for samples containing about 22,000 different words. According to Zipf, such samples should contain about 200,000 words, which, of course, is far from embracing all the richness of language. Then it turned out that formulas of numerical arrangement were valid when applied to individual works of fiction. They were never applied to arbitrary lexical samples—excerpts from books or their conglomeration presented as one sample.

There even arise doubts as to the actual existence of the numerical arrangement of language. Mathematician Yu. K. Orlov, an expert on this problem who devoted more than 20 years to its study, gives an explanation removing all criticism (Orlov, 1980):

> . . . Estoup-Condon-Zipf-Mandelbrot law proved to be the law not of the language but of the text, the law of an individual, highly structured communication intended for calling attention of the maximally broad audience. Non-fiction texts (scientific, technological or philosophic) hardly obeyed the law. Huge samples claiming to represent "language as a whole" did not obey it altogether. (p. 82)

Thus, for the texts we receive

> . . . the harmonious sequence of numbers which in antiquity Pythagoras obtained for the vibration of a string and which forms the basis for the so-called natural sound-sequence (and since all the other musical sound-sequences may be regarded as an approximation to the natural

[6]This paragraph is based on an article by Yu. K. Orlov (1980).

one, for all the musical scales in general). This analogy seems to have a deep significance. . . . (p. 74)

At the same time Orlov emphasizes the fact that whether or not the text (a sample of 22,000 words) obeys Zipf's law follows, as may be readily shown, from the numerical value of the constant d which, according to the calculations by linguists, was approximately equal to one-tenth. Otherwise, in the highly organized texts of our language the order is set by number, setting the constant d.

Now let us stop for an instant and conduct a mental experiment. Imagine that people left the Earth mutilated and wasted by them. Soon the Earth was visited by researchers–metaobservers, alien to our verbal culture. Discovering numerous written symbolic systems, they would naturally start studying them primarily from a statistical viewpoint. They could immediately discover Zipf's law and everything connected with it. Metaobservers would have to acknowledge that among the systems under study they found some that had a highly numerical arrangement. Hence, they could conclude that these symbolic systems were meaningful: they were semantically charged texts. Actually, for us it is difficult to imagine how this semantics can be comprehended outside the cultural tradition and succession. The interest in these texts would rapidly decrease, though the phenomenon would be surrounded by myths (there is always an urge to solve an enigma) which skeptical newcomers from another planet would regard as mysticism.

Note that the law of Willis known in biotaxonomy is also described by the Zipf distribution (recorded this time in a generalized form),[7]

$$P_n = \frac{d}{N^{1+d}}$$

We deal here with the distribution of taxons of higher ranks according to the number of taxons of the next, lower rank they contain. For example, it may be the distribution of genera according to the number of species in them. There proves to exist a substantial analogy with what is observed in written texts. Hence, it follows that the metaobserver should have perceived the variety of texts. However, the meaning of these texts remains vague for the biologists as well. Whereas Meyen (1978) attaches great general biological significance to Willis's law though he believes it to be enigmatic, the paper by Kafanov and Sukhanov (1981) contains the following:

> We feel, however, that systematicians won't lose anything if they do

[7]In this formula P_n is a relative number of taxons each of which contains N taxons of the next, lower rank; d is a constant.

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> not make use of this law in practice. In any case classification patterns will not change much, and any biological interpretations of Willis-Zipf law, to our mind, will remain groundless. (p. 349)

The above lines seem odd: they quite obviously reflect deep distrust toward expressing the results of biological observations by number. How can this hostility to number be accounted for?

In Search of a Number Structuring the Biosphere: Chislenko's Phenomenon and Other Numerical Manifestations of the Living World

Now I would like to expose the reader to the phenomenon discovered by L. L. Chislenko: it was pondering this phenomenon that finally led to the thoughts presented here. Recently, Moscow University Press issued his book, *Structure of Fauna and Flora in Connection with the Size of Organisms* (Chislenko, 1981)—the result of more than 20 years of work. I would call its genre probabilistic–statistical biotaxonomy. The original task is formulated by the author as follows:

> The principal problem under study is: whether the relations between taxons form a system (what we have in mind is not the taxonomic system of kinship, but the system of their actual interrelations in nature), or taxonomic groups of higher ranks represent a catalogized list of similarities and differences, while actual relations of organisms may be exhaustively characterized by the relations between individuals, or between species within the sum total of biocenoses, or between the latter within the biosphere.

Wishing to demonstrate the existence of a taxonomic system of actual interaction, the author applies a probabilistic approach[8]:

> Since taxons are manifold objects, the structure of their relations cannot be rigidly determined; it must necessarily be of a probabilistic nature. (p. 16)

However, here immediately the question arises: what is to be measured when a probabilistic–statistical taxonomy is constructed?

[8]A similar idea, though expressed in a slightly different way, is developed in a paper written by S. V. Meyen and me (Meyen and Nalimov, 1979; see also Nalimov, 1982). It is to be noted that the papers of this trend do not in any way deal with the study of similarity on the level of protein structures, enzymatic systems, or the genetic code, but with the quantitative estimation of similarity and difference emerging as a result of the actual interaction of organisms in nature.

> Quantitative comparison of taxons along definite properties is a sufficiently complicated problem since the variety of organisms is so great that comparable and measurable properties are hard to discover; e.g., what common and commeasurable properties have a bird, a jelly-fish, and a yeast cell? Such properties must obviously be extremely general and abstract.
>
> *Proportions seem to satisfy those requirements most completely.* Simplicity, abstraction, measurability and principal comparability of this property need no proof. (pp. 16–17)

Now a few quotations concerning the procedure of measuring and of data presentation.

> Each taxon is regarded as an aggregate of species. The datum is represented by the proportions of body for each species, which is obtained unambiguously. (p. 22)
>
> . . . the research started with selecting for the given group or area of few most important sources, as up-to-date as possible, that contained the maximal possible information we need. (p. 23)
>
> From the sources selected once and for all we then proceeded to extract all the information we were interested in: taxonomic dissection in the group, various characteristics of proportions, bodily properties, etc. In case of necessity we also measured bodily proportions from drawings, if they were not indicated in the text and if the weight was not given. Proportions of each species were given as maximal of the adult individuals. Only those measures were taken into account that characterized sufficiently the volume of the body as compared with the structures within other groups. As a rule, we discarded the length of all possible appendages like plaits, thorns, fins, or tentacles, etc., if their volume was *incomparable with that of the body.*
>
> All the data expressed in concrete metric units—microns, millimetres—were subjected to logarithmic transformation and were thus expressed in logarithmic units. Such units were plotted on dimension scales and were fully denominated as "scale logarithmic units". . . . In the paper, the reader will often come across "reduced linear proportions" of the species. This expression signifies geometric average of their length, height and width of the maximally large individual of the given species provided that the selected measures sufficiently reflect the volume of the individual measured (i.e., without the above-mentioned long and thin appendages). (p. 24)

The results of the analysis made by Chislenko are presented graphically in 62 drawings. They embrace mammals of the world, reptiles of the world, vertebrates of the USSR (mammals, birds, reptiles, amphibia, freshwater fish, fish of the Northern seas and the Black Sea); insects of the European part of the USSR; higher plants of the USSR; bacteria and actinomycetes of the world; phytopathogenic viruses of the world; parasites of the freshwater fish of the USSR; pelagic populations of the world ocean.

Having included such a heterogeneous list in his research, the author still had to answer the question: What can be said to represent proportions of an individual organism? In the process of solving the problem there was developed a biometrological language setting the rules of fixing proportions of an organism. Like any language, this one is also arbitrary. Perhaps, an endless number of languages for the same purpose could have been proposed. The discussion of which one is better will be meaningless, but if we still feel like arguing about this point, we shall have to invent a metalanguage, and it will not necessarily be the only one possible.

To evaluate the language, only texts that are constructed in this language can be used. If they prove to be interesting, the language acquires the right to exist, though this is not to say that other languages cannot arise.

Chislenko's texts are distribution functions. They are undoubtedly interesting. Let us consider them, at least briefly.

Figures 1 and 2 represent two families of curves obtained by Chislenko. They are typical families. Here is how the author himself comments on them:

> In the overwhelming majority of cases, distribution of the number of species (if it is sufficiently great) within the taxons of a higher rank on the logarithmic scale is represented by a symmetric curve and, as far as we can judge, it does not contradict the opinion by A. M. Hemmingsen (1934). In the present paper we quote only a small part of the distribution we have obtained, primarily due to the lack of space. Naturally, if the number of species in a taxon is small, a lot of different forms of distribution may appear, merely because of the insufficient material. In the taxons of lower ranks (genera, families) embracing a great number of species, the symmetry of distribution is especially marked. Distribution of species within the taxons of higher ranks is more often than not also symmetric or approximately symmetric, which is generally supported by the whole material analysed. (p. 182)

Chislenko also makes an interesting observation concerning the arrangement of proportions,

> We usually understand the arrangement of proportions relations as the position of curves or averages at a definite distance from one another, either in groups or individually, on the logarithmic scale of dimensions. Distance between them occupies the range between .45 and .60 logarithmic units and on the average equals .50 units. As a rule, the indicated

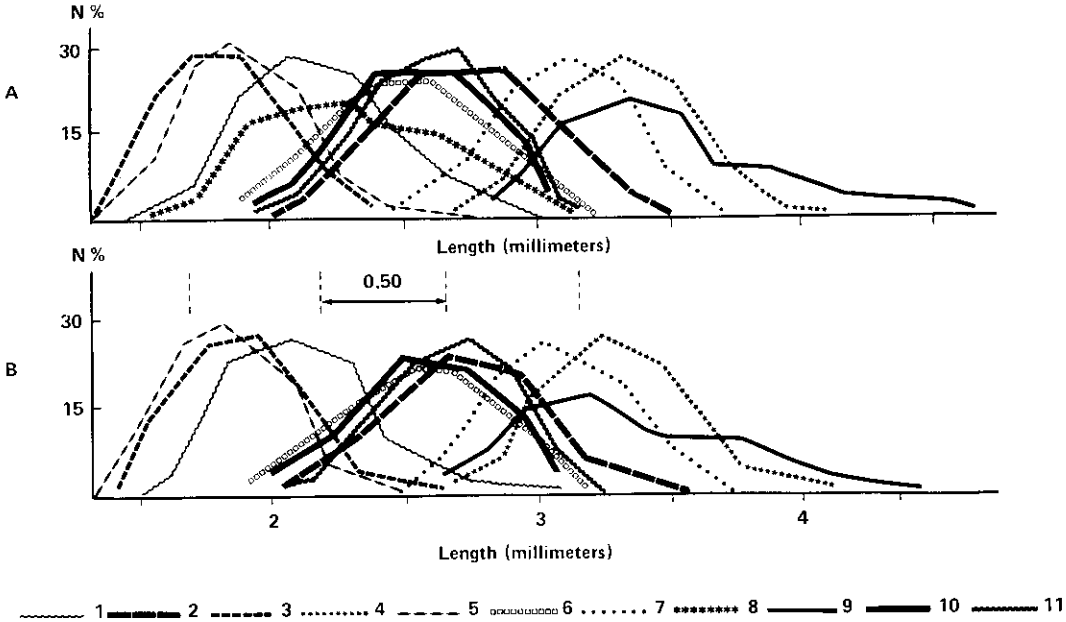

Fig. 1. Percentage distribution of the number (N) of genera weighted by the number of species composing them, depending on bodily length (L), for the various groups of the World mammals: (A) according to bodily length and (B) the same, corrected with respect to weight. Curve 1, *Rodentia;* 2, *Carnivora;* 3, *Chiroptera;* 4, *Pinnipedia;* 5, *Insectivora;* 6, *Primates;* 7, *Marsupialia;* 8, *Artiodactyla;* 9, *Getacea;* 10, *Lagomorpha;* 11, *Edentat.*

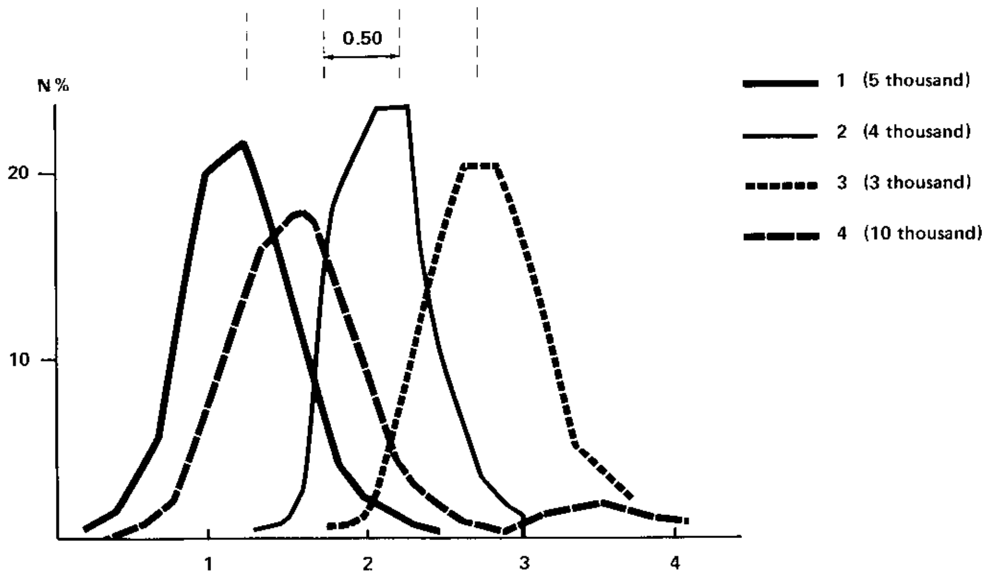

Fig. 2. Percentage distribution of the number and species of certain groups of unicellular organisms depending on the reduced linear dimensions. Curve 1, freshwater weeds; 2, *Radiolaria;* 3, *Foraminifera;* 4, generalized curve for free-living *Caliata*, sea-water pelagic *Flagellata*, seawater pelagic *Diatomea Testacea*, freshwater *Amoebina*, protozoa parasitizing on the freshwater fish of the USSR.

> range has narrower limits. We do not set ourselves the task of studying the nature of the constant discovered. This is only possible under condition of a sufficiently complete review of the material that reveals the constant. In the present material it concerns only bodily proportions and expresses "biotaxological" relations: otherwise, it may be discovered only by the specific procedure of weighting the property in question by the number of taxons that possess this property. We have at our disposal vast material showing that the constant of .50 logarithmic units revealed by the given procedure is not necessarily and exclusively related to bodily proportions. It is also revealed after the analysis of the shape of the body, of fertility and number of taxons. The corresponding data are being published. It is possible that a number of other properties will, after a "biotaxological" analysis, yield the same constant. General analysis of data related to the problem is yet to be made. As to the numerical value of the constant, it may be connected with π, since the value of .50 logarithmic units equals logarithm of π to within the second digit after the decimal point. However, we do not have sufficient proof of such connection. (p. 186)

What follows from the above quotations? First of all, I would remind the reader of Plotinus's words about the numerical nature of the world. The living World in all the variety of its manifestations is seen as a system with a rather high numerical organization. Our attention is hypnotized by the constant π. However, it is, perhaps, more relevant to assert that the constant is *three* (approximated multiples of distances to medians for the distributions on linear scales) whose significance for our interaction with the World was discussed earlier.

Now let us consider other numerical parameters of biology. First, recall the numerical relations for the split of the hybrid descendants into the initial parental forms raised by Mendel in his famous experiments with peas, 3:1, 9:3:3:1.

Again the notorious three. It brings order to the seeming disorder of changeability. Genetics discovered the inner meaning in the "striking regularity" (in Mendel's words[9]) of numerical relations of heredity of pea properties. However, the law of independent heredity postulated by Mendel has a limited manifestation: we more often observe "coupling" for a set of genes and properties controlled by them.

We come across the number *three* directly in the genetic code. The code of nucleic acids is a *triplet*. The words of the genetic code are also

[9]The prolonged dramatic refusal to accept Mendel's discovery so impressively described by Golubovskii (1982a) is interesting and instructive. The essential thing was that discrete-numerical description went against the typical nineteenth-century concept of the continuous World order (Mendelson, 1980). It seems relevant to ask to what extent the acceptence of Mendel's ideas was hindered by the fact that the same number *three* again acquired an almost sacral significance in a science fighting against obscurantism.

triplets: 64 triplets are put into correspondence to 20 amino acids.[10] Note that 64 is a square of the cubic number 8, though this may be superfluous for comprehension of the numerical game played by nature.

It is noteworthy that the symmetric encoding table consisting of 64 elements can be obtained by proceeding from another problem formulation. Assume that we are dealing with 6 variables $x_1, x_2, \ldots, x_6$, each of which may take only two values: $+1$ and -1. Now let us construct the matrix so that its lines would contain one value of each variable and each line would be different from the rest. It can be readily shown that there will be 64 such lines. Such constructions are part of the so-called Hadamard matrices: they possess certain nice mathematical qualities and are applied both in the theory of optimal encoding and in experimental design. Now the curious fact is as follows: in the ancient Chinese *I Ching* (*Book of Changes*) (Anthony, 1980) which recently became so widely known, the philosophical attitude to various problems is explained through interpreting 64 hexagrams, incomplete lines of Hadamard matrices transformed into columns[11]; the binary symbols are represented by a dash and a broken dash (Fig. 3). We see that a matrix containing 64 words proves to be sufficient to encode (in the hereditary transfer) all the variety of the living World and also to express the attitude of Chinese philosophical thought (both Confucian and Taoist) to the variety of problems which man has to face; sometimes it is sufficient for the solution of modern technological problems. It is noteworthy as well that in the *Book of Changes* (when it is used for practical purposes), similarly to the biological code, the rigidity of language is softened by resorting to chance.[12] Are such comparisons

[10]The necessity of a triplet code is at first sight easy to explain. The primary alphabet of the genetic code consists of four bases: adenine, guanine, thymine, and cytosine. Four bases taken separately may encode only four amino acids. Combinations of two bases each are also insufficient: they determine only 16 amino acids. The number of all possible combinations of three is already more than necessary. The code structure proves to be redundant, which does not remain without use in the language of the biological code. However, why exactly 20 amino acids and 64 RNA? The purely geometric explanation of the connection between the numbers 20 and 64 is given by A. G. Volokhonskii (1971). The series of 2^6 numbers yields a set of elements for a five-dimensional simplex: 1 center, 6 bounds, 15 edges, 20 two-dimensional sides, 15 three-dimensional ones, 6 four-dimensional ones, and 1 five-dimensional. The three-dimensional projection of this simplex is an icosahedron, a figure with 20 sides. Then it becomes possible to put each amino acid into corresondence with a definite side. (Note that this circumstance is emphasized in the well-known book by Eigen and Winkler (1979, p. 67). Thus emerges a new, purely biological fundamental form with a new type of symmetry not typical in the inanimate World. But again the question arises: Is there any profound biological meaning in this? In any case, it is known that viruses consisting of RNA and albumin have the form of regular hexahedrons.

[11]We earlier spoke about the relations between Hadamard matrices and the symbolics of the *Book of Changes* (Nalimov and Golikova, 1981). We showed that 64 hexagrams are nothing more than another form of recording of an optimal design for a 6-factor experiment well known in mathematical statistics.

[12]The *Book of Changes* greatly affected the evolution of the entire Chinese culture. It is extremely versatile both in its contents and destination. It embraces philosophy, revealing the process of emergence, existence, and change; psychology, demonstrating the mode of behavior in various situations; and, finally, this is the book of fortune-telling. The book has been commented upon by many schools. Now the West has

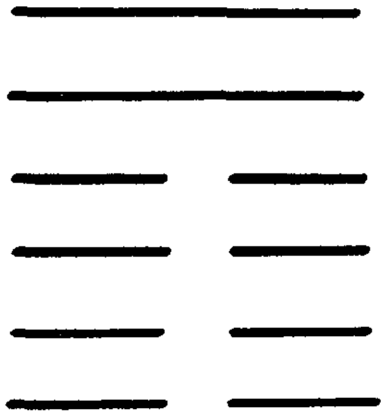

Fig. 3. Hexagram 20: Koan/Contemplation (The ablution has been made, but not yet the offering). The following explanations are given to various characters of the hexagram (up from the bottom).

First line: *Boylike contemplation.* We are not meant to know everything. The ruling Sage is at work and his actions are beneficial even though we cannot understand them. . .

Second line: *Contemplation through the crack of the door.* While everything is progressing, slow progress is the only enduring progress. . . . A man of affairs must learn to rely on his inner power, and realize things that he cannot see.

Third line: *Contemplation . . . decides the choice between advance and retreat.* We need not worry about the time required to make progress; everything will happen as it should.

Fourth line: *Contemplation of the light of the kingdom.* In following our path, in relating correctly to all situations, we lessen suffering in the world.

Fifth line: *Contemplation of my life. The superior man is without blame.*

Sixth line: *To know how to become free of blame is the highest good.* The superior man corrects himself. (Anthony, 1980)

relevant? Is it legitimate to ascribe meaning to such numerical coincidences, and if so, then what meaning do they have? If we are ready to perceive the World as a text, should we not be cautioned by the fact that the concrete languages of this text are sometimes strikingly alike?

Another instance of *trinity* is the system ABO which forms the four principal blood groups: O, A, B, and AB. It is common knowledge that belonging to a blood group determines the general medico-biological status of a person. It gives rise to a lot of statistical problems of human genetics: the study of sharp variability in the distribution of blood groups among various world populations; distribution of ABO in the population of healthy people and those suffering widespread and sinister diseases such as smallpox, tuberculosis, leprosy, typhus and paratyphoid, and cancer. Here interesting patterns have been obtained, though many facts are still of a debatable nature (Mourant, 1977). The problem of blood group is,

begun to comment on it. For us it is especially important to note that, when the *Book of Changes* is used to tell fortunes or to choose a mode of behavior harmonizing the personality, it proves necessary to introduce an element of chance. For example, in the book by Anthony (1980), though written by a Western author, the hexagrams and their lines to be interpreted are chosen by tossing a coin.

perhaps, one of the most acute among the problems in medicine connected with number.

Thus we see that Chislenko's parameter expressed by the number *three* is not alone in biology.

However, from a general biological viewpoint, the study of the part played by number in the living World has not yet begun. I have not seen a single publication which would collect and subject to analysis from a single standpoint the numerical parameters which biologists have come across.[13] Nothing similar to what physicists have done to comprehend and interpret physical constants has been done in biology.[14]

If any assertions concerning biological numerical parameters are relevant at all under our limited knowledge of the subject, they will be as follows. Biological numerical constants do not play the role of fundamental constants. In contrast to physics, they do not enter fundamental equations, for the very reason that biology lacks such equations. And perhaps this is just because it lacks fundamental constants. The living World does not have the rigidity typical of the inanimate World. Therefore, the living World does not need fundamental constants—they have nothing to guard. In this World everything is in a mobile, swimming equilibrium balancing stability and changeability.[15] (Naturally, we do not consider here the biophysical equations that are of no fundamental importance in biology.)

And if the living World is a text, it is not at all easy to find a scientific language to translate it. The scientific language of today has rigidity attached to it by physics. In particular, the book by Chislenko was attacked by some biologists just because, in his attempt to embrace metrically almost all the living spectrum, he tried to attach to the language of

[13]I have dwelt in detail on the number *three* since, on the basis of what is said above, it seems to have a structuring function. Perhaps it would be of interest to consider the role of number in producing the symmetry (or asymmetry) of biological forms. In what way is the multitude of forms distributed among the numbers arranging their symmetry? However, *a priori* it is not clear whether any meaningful conclusions can follow from this.

[14]Perhaps, it is pertinent to show that one of the fairly serious attempts to search for biological constants is the search for the number characterizing the minimal size of a cell. The difficulties of this project are well described by Morowitz (1967). Note also that in the book by Peters (1983) devoted to the ecological implications of body size a vast material has been accumulated showing that a wide class of numerically measurable biological manifestations in animal ecology is still of a somewhat statistical nature.

[15]The search for a rigidly fixed number in biology that would be analogous to the numerical values of the fundamental constants in physics unavoidably leads to vexing misunderstandings. For example, Zhirmunskii and Kuz'min (1982), proceeding from the analysis of allometric dependences of growth, claim to have discovered a new constant: the ratio between the consecutive critical values of the argument when the system passes into a new stable state was equal to $e^e = 15.15426$. In a review Polikarpov (1983) warmly supported this conclusion. At the same time, in another review Volkenshtein et al. (1983) demonstrated both a failure to make a mathematical conclusion and its inadequacy for the actually observed phenomena. The validity of criticism follows also from the most general considerations: the curves of allometric growth are still nothing more than the approximation formulas, and they may always be given analytically in different ways.

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measures the softness which already bordered on arbitrariness. But how could he act otherwise without abandoning the task he set for himself?

It is of interest to compare this approach numerically with that of Peters (1983), who used body mass of animals as a criterion to reveal similarity in the living world. (For details see chapter 3, section 4.13 of Peters' book.) The two approaches can be regarded as mutually complementary. I am not able to dwell here on this subject, but its development in the future is predictable.

Chapter 3

Global Evolutionism as Revelation of World Semantics Through a Probabilistic Measure

Introduction

Still, number plays a crucial role in the living World: to my mind, it acts in a transformed mode, as a probabilistic measure. It is in the language of probabilistic measures that evolutionism, the principal scientific conception of the living World, may be considered without falling into numerous logical traps.

Philosophically, difficulties linked with the comprehension of the idea of evolutionism are well known. I quote Tomlin (1977):

> The truth is that evolution *was an hypothesis which hardened into dogma before it had been thoroughly analyzed.* Hence it mothered a number of fallacies. It was easy to say that the idea of change or transformation in nature had been substituted for that of immutability; but what sort of change was involved? If species were no longer regarded as immutable the fact remained that they exhibited a measure of stability, or they would not have deserved the name of species. Evolution was conservation as well as transformation. And if the human species possessed a unique character, wherein the evolutionary process acquired inwardness and conscious direction, this still did not prove that evolution had "led" to man. Until man's fortuitous and unaccountable advent, it had appeared to lead nowhere; and this was not merely perplexing, but it placed man outside rather than inside the evolutionary process. (p. 228)

A skeptical reader could add that man must be placed outside the evolutionary process, for otherwise evolution must be assumed to be ultimately directed at destroying what had been created in the process of life development and, moreover, at making impossible (due to the exhaustion of the Earth resources) the repeated cycle of a highly developed form of life. Evolutionism, if regarded as a process directed by some rigid regularities (only slightly softened by the randomness of mutations), is seen as a manifestation of the demoniac principle: we return here involuntarily to gnostic mythology.[1] Perhaps the supporters of traditional evolutionism following the logic of gnosticism will have to claim that the idea of evolutionism should be separated from the actual evolutionary process.

Such traps can be surpassed, it seems to me, only by resorting to probabilistic thinking.

Now it seems relevant in a general philosophical aspect to try to construct a model of global evolutionism (Karpinskaya and Ushakov, 1981)[2] invariant to all the specific features of individual concrete evolutionary processes. An attempt at simulation of the evolutionary idea carried out on such a highly abstract level might help to reveal the common features implicit in the idea of evolutionism if it is submerged into the *indefiniteness* typical of our contemporary outlook that makes it sound probabilistic.

If we proceed from the concept that the living World is a text, we should first of all try to understand the structure of the language in which the text is written. Any sufficiently rich language combines two elements: the discrete (the word or any of its discrete analogs) and the continuous (the continuous semantic field underlying words). I showed (Nalimov, 1981a, 1982) that the combined application of the two complementary elements, the discrete and the continuous, essentially deepens our comprehension both of the functioning of human everyday language and of consciousness itself. Now I shall try to expand this approach to deepen the comprehension of evolutionism.

In biology words of the intermediate pre-textual level are represented by codons; in ecosystems, where the biological text is revealed, the discrete element is already represented by an individual, a species, or any super-species formation. The continuous element is represented by biological semantics, i.e., by the entire possible variety of morphophysiological properties ordered on a numerical continuum in the same way as, for example, the entire perceived variety of the color spectrum is ordered on the

[1]Gnostic myth about the World order has been elaborated in detail and can hardly be retold briefly. Everything is complicated by the fact that there existed many gnostic systems whose ideas of the World order differed essentially. However, the main idea can be expressed, if somewhat schematically, as follows. The World was not created by God. The World is governed by angels, demiurges, or demons of the original Darkness. The God of gnostics is alienated from the World. He is described as: non-existent, unborn, indestructible, unknowable, incomprehensible, super-celestial, immutable, self-begotten (Jonas, 1958).

[2]The review by Karpinskaya and Ushakov (1981) embraces a wide range of papers (its bibliography includes 31 titles) concerning the philosophical problems of evolutionism. It analyzes the view of Teilhard de Chardin (1965), Dobzhansky (1973a, 1973b) Simpson (1973), Dawkins (1976), Toulmin (1972), and others. In the review the fact is emphasized that the problems of global evolutionism often arise in the comments on the heritage of the French philosopher, biologist, and theologian Teilhard de Chardin. We cannot help but acknowledge that the most meaningful, though at the same time somewhat contradictory, comprehension of the idea of evolutionism was achieved in biology. The history of the development of the idea of biological evolutionism proper is presented in detail by Mayer (1982).

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long-wave scale. The semantic continuum represents a yet unpacked text. The model suggested here is aimed at indicating how the semantic continuum can be unpacked without decomposing it.[3]

Long ago, biologists intuitively started to feel the necessity of introducing into consideration a biological continuum. Darwin was among them. The history of the relations between the discrete versus the continuous in science (and, in particular, in biology) is considered by Mendelson (1980). Simberloff (1980), analyzing the succession of paradigms in ecology, also includes some considerations to the point. It is noteworthy that in geobotanic research (Curtis, 1955; Whittaker, 1967) the continuum was also employed.

Criticism of Particular Theories

Here I shall confine myself to two examples illuminating the limited capacity of models that proceed only from the discrete constituent. One of them is a highly critical article by B. M. Mednikov (1980). The author remarks that in population and evolutionary genetics the most popular are mathematical models based on the ideas of Beanbag Genetics. This is a far-reaching simplification: genes behave within the genome as discrete units whose interaction is negligibly small; the selective value of each allele is constant; the selective value of genes is additive. Such an approach may lead to great achievements (J. Haldane, R. Fisher, S. Wright), but, according to Mednikov, these models are not isomorphic to reality. They do not take into account two essential phenomena: gene pleiotropy and attribute polygeny. The selective value of the gene proves not to be constant (effect of the gene position in a genome), and the concept of "attribute" is so fuzzy that it cannot be perceived discretely.

The second illustration is a philological paper (Ivanov and Toporov, 1975). The authors resort to information-theory reformulation of the evolution of mythological texts proceeding from the well-known, though naive (in my opinion), ideas of Monod (1972). Here again, one may observe the concept of the discrete character of language and also, it seems, the additive effect of noise on the initial text. The transfer of Monod's ideas to the culturological script, which is easily traced historically, has proved to be a specific crucial mental experiment jeopardizing the conception. Within

[3]The fact that the semantic field cannot be unpacked by decomposition is built into the concept of its continuity. For any two points a and b on the continuum it is always possible to find such a point c that $a < c < b$; i.e., between two arbitrarily close point-like morphophysiological properties it is always possible to discover the third one. Decomposing the continuum into two subsets, we must indicate the point of division which may be arbitrarily referred to either of the two subsets (the Dedekind axiom of continuity). No continuum can be decomposed into the union of the countable family of disjoint closed sets (theorem by Sierpinski): here lies the principal unsolvability of the classification problem based on decomposition.

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such a system of notions no clear-cut changes of cultures (e.g., the emergence of Christianity or Islam) can be described. The new texts that gave rise to the above historical phenomena did not emerge as a result of the accumulation of random errors in an initial text.

Global Evolutionism: A Bayesian Approach

Let us proceed from the fact that there exists a semantic field μ on which a differential distribution function is given (probability density), $p(\mu)$, characterizing a selective manifestation of this field. A probabilistically weighted manifestation of the semantic field makes the premises on which the actual, observed text is constructed relatively commeasurable. Evolution, as it is, signifies the change in the correlation of premises in correspondence with the Bayesian *syllogism*,[4] to which I have invariably resorted in my recent books (Nalimov, 1981a, 1981b, 1982).

$$p(\mu \mid y) = kp(\mu)p(y \mid \mu)$$

Here $p(\mu)$ is a prior distribution function that preceded the evolutionary impetus, $p(y \mid \mu)$ is a conditional distribution function setting the evolutionary impetus in a new situation y, k is a normalizing constant, and $p(\mu \mid y)$ is a posterior distribution function generating a new text. The model makes use of both complementary constituents: the continuous (scale μ) and the discrete (distribution function is given by individual, discrete parameters). Arguments of the Bayesian model are neither physical space nor time, and that makes it invariant to individual particular evolutionary processes.

Despite the fact that the Bayesian model does not explicitly contain astronomical time, logically it links in a non-trivial way three modes of time[5] inherent in our perception: Past, Present, and Future. Function $p(y \mid \mu)$ may be regarded as a question posed from the Future to the Past $p(\mu)$ in connection with the situation y, either newly formed or foreseen in the Present. In other words, $p(y \mid \mu)$ signifies the *spontaneity* of choice from the Future that exists only as an unrealized potentiality. From the standpoint of an external observer, spontaneity may be regarded as a manifestation of chance, if chance is seen as unpredictability. However,

[4]In my interpretation, the Bayesian formula well known in statistics acquires a new meaning. From an auxiliary computational formula, broadly used in mathematical statistics, it turns into one setting the logic of propositions. That opens up the possibility of calling it a Bayesian syllogism, a generalization of Aristotelian categoric syllogism to the case when both initial premises and corollaries are of a fuzzy, probabilistically weighted nature. The term "Bayesian syllogism" is new, having been introduced in my earlier book (Nalimov, 1982).

[5]This is a mathematical interpretation of the well-known assertion by Heidegger (1960) of the interpenetration of three modes of time.

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unpredictability is now not reduced to the concept of "noise." Randomness is no longer brought down to the choice between zero and unity: it represents an unpredictable generation of a new text based on the redistribution of weights over the entire scale μ. Evolutionism considered through the Bayesian syllogism makes our idea of the nature of chance in evolutionism more profound. Chance is rehabilitated: it is no longer a synonym for nonsense. The opposition of directed versus random that Dobzhansky (1973b) connects with the names of Teilhard de Chardin (1965) and Monod (1972) proves to be a result of the simplified understanding of the nature of chance.

Evolutionism itself now signifies numerical unpacking of the whole potential variety of morphophysiological properties given on the numerical continuum. Here we involuntarily come back to Plotinus's concept that the World variety is a numerical revelation of what was determined by number as integrity.

Now let us return to the book by L. L. Chislenko (1981). His data may be regarded as an illustration of the Bayesian model of evolution. The initial data, bodily proportions, are plotted on the scale μ. Taxons of higher ranks represent probabilistically weighted unpackings of the scale. Weighting is carried out according to the percentage of the taxons of lower ranks with equal body lengths within the taxons of higher ranks. We deal here with one of the possible versions of the probabilistic representation of a morphological manifold given concrete numerical values. A morphological manifold thus presented may be regarded as a result produced by the Bayesian mechanism.

Two Illustrations of the Model: Nomogenesis and Neotenic Evolution

The interest in Nomogenesis[6] (Berg, 1969) is illustrated by the recent re-edition of Berg's book in the USSR, as well as by its publication in English. Not being a biologist, I refrain from making any evaluation of Nomogenesis.[7] The important thing for us is that this conception was in obvious opposition to the paradigm of simplified discrete-mechanistic notions known as Beanbag Genetics.

The basic premises of Nomogenesis are as follows: the initial faculty of an organism to respond expediently; evolution as development of already

[6]A composite word derived from the two Greek words *νομο*, the law, and *γενης* (*γιδνομαι*), to come from.

[7]I do not give here a detailed exposition of Nomogenesis, assuming that it is known sufficiently well. A compact and critical summary of nomogenesis appears in the preface by K. M. Zavadsky and A. B. Georgievskii to the 1977 edition of Berg's book. The paper by Lubishchev (1982) also contains interesting remarks concerning nomogenesis.

existing faculties; the extrapolation of the ontogenetic programming to phylogenesis; the directed nature of changeable heredity; formation of species as macromutation; the idea of the primordial character of initial variety—parallelism and convergence and basic primary regularities.

Automatic orthogenesis[8] proves to be the principal law:

> . . . the unknown force innerly inherent to the living nature and acting independently of the external environment and directed towards greater complexity of morphophysiological structure. (Berg, 1977, p. 29), (quoted from the Russian edition)

However, two types of evolution are acknowledged: evolution based on the preliminary adaptation and the immediate adaptational effect of the environment—the landscape. The point is that evolution of such complicated organs as an eye, an ear, or a brain requires simultaneous and concordant, and therefore hardly probable (if everything is explained by random micromutations), modifications of a multitude of attributes; otherwise the organ will be destroyed.

The Bayesian syllogism allows us to link the basic postulates of Nomogenesis into a harmonious system of well-structured propositions permitting their further elaboration by means of introducing probabilistic notions comprehended more profoundly than in the evolutionary teachings of today.

1

There exists the following regularity: from the two premises $p(\mu)$ and $p(y \mid \mu)$ necessarily follows $p(\mu \mid y)$; two premises and the corollary set general limitations to the formative process; the emergence of some common (congruous) new information $p(y \mid \mu)$ creates the formula of limitations that Lubishchev (1982) called telogenetic similarity, i.e., ". . . similar solution of definite problems independently of the nature of factors realizing this solution . . . similarity between ichthyosauruses, dolphins, and fish, between eyes of the vertebrates and cephalopoda. . ." (p. 79).

2

Evolution consists in revealing faculties imprinted in the first premise $p(\mu)$ that evolves itself: at the fist step $p_1(\mu)$ passes into $p_1(\mu \mid y)$ that at the second step becomes the premise $p_2(\mu)$ acting as a filter with respect to the new information $p_2(y \mid \mu)$; on the whole, the evolution proves to be nothing

[8]Orthogenesis (or orthoevolution) is the evolution of the living Nature leading directly to the future adaptation.

more than discrete unpacking of the initial semantic field existing in nature.

3

Faculties are manifested through the emergence of the new information $p(y \mid \mu)$ that can be regarded as a response to the emergence of the new landscape y and as pre-adaptation.[9] The Bayesian syllogism, free from temporal order, allows us to anticipate events. Man, in his social behavior, always makes use of forecasting that has a probabilistic nature and can be described by the Bayesian model as well.[10] Is this not what happens in nature, where Bayesian anticipation also takes place?

4

Emergence of the new information $p(y \mid \mu)$ may be regarded as an expedient action. Spontaneity is a generally unpredictable direction of action. This is how we are prepared now to interpret the term Nomogenesis introduced by Berg.

5

Parallelism and convergence (instead of Darwinian divergence): $p(y \mid \mu)$ interacts simultaneously with a multitude of initial states $P_A(\mu)$, $P_B(\mu)$, . . . , producing various species.

[9]It was Darwin who first noted that indifferent or even harmful attributes may accumulate, and when the environment changes sharply, they may suddenly prove very useful. However, for Darwin pre-adaptational attributes always were of a purely random character, that is, they were absolutely neutral with respect to the future. The existence of pre-adaptation at present is beyond doubt (Georgievskii, 1974). Discussions seem to concern only the nature of this factor and the part played by it in evolution. The important feature for us is only *that from the probabilistic character of pre-adaptation does not follow its* neutrality for the future. Another aspect of the problem is also of great interest; namely, if pre-adaptation means anticipation allowed by the Bayesian model, how far can it go? This problem is especially acute in the anthroposphere, where the environment includes social and psychological factors. Perhaps what is now happening before our eyes is such a rapid change of the environment in the anthroposphere that man is biologically incapable of equally rapid preparation for the change beforehand, on the pre-adaptational level. This disastrous lagging behind *may be occurring now. And if this is really so, the situation will be getting* more dramatic since the rate of change of the environment increases and the increase is perhaps exponential.

[10]All our decisions are based on forecasting. We forecast both on a small scale—leaving our home in the morning and sketching the day to come—and on a large scale—entering a college, getting married, or taking a job. Forecasting is related to re-construction of the distribution function of value concepts $p(\mu)$ in correspondence with the new task y emerging in a *new, still closed situation. Forecasting always consists in* anticipating events manifested by the appearance of the filter $p(y \mid \mu)$ interacting with the previously existing value system $p(\mu)$. A case in point: Kutuzov, a Russian noble, patriot and general during the Napoleonic invasion of Russia, made a decision to abandon Moscow to the enemy. This decision could not stem only from his lifetime value concepts. The new crucial situation changed them by force of the anticipated consequences.

6

Not just one attribute is changed, but the distribution function given on the whole field of attributes; even if we keep in mind the dominant attributes, their change (due to the normalization of the distribution function) will modify the probabilistically given weights of the remaining attributes.

7

The Bayesian syllogism can be applied to describe super-species formations, e.g., a genus [by the way, that allows for the possibility that generic attributes may be newer than those of a species (Lubishchev, 1982, p. 97)], biocenosis, or even an ecosystem as a whole.

8

The program of ontogenesis may be extrapolated to phylogenesis: while the former is programmed via $p(\mu)$, the latter is programmed via multiplicative interaction between $p(\mu)$ and $p(y \mid \mu)$.

9

The Bayesian syllogism, in accordance with Nomogenesis, ignores the creative role of natural selection. However, what we keep in mind is not complete rejection of natural selection as a factor of evolution but the abandonment of the concept of evolution as a random search.

10

From what is said above it can be easily seen that using the Bayesian syllogism as a model for evolutionism allows us, on the one hand, to coordinate logically the postulates that have been considered inconsistent by some critics of Nomogenesis [e.g., directed increase of complexity (pre-adaptation) and immediate effect of the environment] and, on the other hand, to expand the initial premises without breaking the harmony of the theory. For example, Berg had to exclude regressive evolution from consideration; the Bayesian syllogism, because of its flexibility, does not require that. Even more essential is that Berg had, in the name of regularity, to reject completely randomness. The Bayesian syllogism retains the necessity typical of syllogistics, but both the initial premises and corollaries have a probabilistic structure.[11]

[11] Here an analogy with the Schrödinger equation

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi$$

seems relevant. Its recording is of a deterministic character, while the ψ-function entering it has a probabilistic nature. This fact was first pointed out by Born.

11

M. D. Golubovskii (1981) underlines the nomogenetic character of the law of homologous series and hereditary mutation formulated by the famous Russian geneticist N. I. Vavilov. The law includes two postulates,

> 1. Genetically close species and genera are characterized by similar series of hereditary changeability with such a regularity that if we know a series of forms within a species, we may foresee parallel forms in other species and genera. The closer genetically are genera and linneons[12] within the general system, the more complete their similarity *in the series of their changeability.*
>
> 2. Entire plant families are commonly characterized by a definite cycle of changeability penetrating all genera and species. (p. 80)

Discussing those postulates, Golubovskii writes:

> Otherwise, changeability is in no way chaotic, but has a definite track and may be similar for different species, despite the difference of genes. (p. 81)

In our model the track is given by the emergence of the distribution function $p(y \mid \mu)$ giving rise to similar series of mutation in multiplicative interaction with the function $P_A(\mu)$, $P_B(\mu)$ . . . close in their forms.

12

Nomogenesis has much in common with the concept of Neotenic[13] evolution, which can also be re-interpreted by means of the Bayesian approach. Below is an excerpt concerning the appearance of Homo Sapiens in the above system, written by Coppinger and Smith (1983) in response to *Growing Young* by Montagu (1981).

> When a chimpanzee is born, its brain, compared to the diminutive size of his body, is large, and its arms, short, just like a human infant's. But as the chimp matures, its brain grows more slowly and its arms more quickly than the trunk. By the time the chimp is an adult, its head is small compared to its body and its hands graze the ground. But in adult humans, the proportion of brain weight to body weight is about the same as that proportion in infant chimpanzees or gorillas. Humans, of course, are much more than immature versions of our primate ancestors, much more than apes that will never grow up. But in a way, while the chimp grows out of its immature primate body, a human never does. The child of our ancestor is indeed the father of us all.

[12]*Linneons are Linnaean species.*

[13]The composite word derived from the Greek *νέος*, a young person or animal, a cub, and *τεινω*, to be like someone, to be similar to.

> There are several advantages to the Neotenic hypothesis of human evolution. For one, Neoteny could explain how human speciation took several quantum leaps in the past five million years. Contrary to the conventional mode of evolution, which explains that a species is modified gradually, trait by selected trait, many biologists now believe that speciation is "punctuated," or relatively swift and radical, an idea proposed by Stephen Jay Gould, Niles Eldredge, and Stephen Stanley. Neoteny neatly explains how humans, for example, could look and behave so differently from other primates, like chimpanzees and gorillas, and yet be so similar genetically. The theory of neoteny also allows us to see many seemingly isolated adaptations as part of a single process. Human traits as disparate as erect posture, weeping, hairlessness, investigativeness, and small canine teeth, when seen as a result of neotenic evolution, no longer need separate adaptive explanations. (pp. 50–51)

We know, of course, that a slight (mutational) change in the genetically given system of allometric growth may sharply change the structure of the growing organism. But this is not to say that a primate will turn into a human. The mechanism of neotenic evolution, at least on a symbolic level, can easily be revealed by means of the Bayesian syllogism. Baby primates have dispositions to become people. Some of them, such as brain weight or arm length, are explicit. Others are still latent. The distribution function $p(y \mid \mu)$ should necessarily appear that would be able to reconstruct what has been prepared and set by the function $p(\mu)$. Only what is prepared may be reconstructed so that the organism does not perish. Reconstruction, when prepared, may occur as a series of quantum leaps. The reconstructed creature will be a "spotted" one. But the reconstruction should contain the consistency given by a measure that embraces the entire field of attributes. This idea is not in obvious opposition to the Darwinian conception of continual evolution. The reconstruction takes place on the continuum of morphophysiological attributes, but the process itself is discrete.

The specific relation of brain weight and arm length in the bodily proportions of baby primates, neutral for their interaction with the environment, can be regarded as a case of directed pre-adaptation.

Close to Nomogenesis were evolutionary ideas of the well-known Russian scholar and philosopher V. Vernadsky though, as far as I know, this fact was not reflected in the literature. Here is how his reasoning on the evolution of the brain is retold by Balandin (1982):

> For man cephalization became a dominant process: over a million years (a small span of time in terms of geological history), the volume of the cranium has increased almost four-fold, and the number of nerve cells by dozens of times with the structure of the brain drastically more complicated.

> Strange as it is, such an unusual phenomenon still remains but little studied. If we admit that the evolution of living creatures was by the selection of the fittest among random species, then the cephalization process cannot be explained. The nervous system steadily became even more sophisticated in several stages and at an accelerated pace (the fastest in man's ancestors). Any chance here is excluded. You cannot accidentally devise a spaceship or an "intelligent" computer. And our brain is more elaborate than any spaceship or computer. (p. 182)

What is especially important to emphasize is that Vernadsky indicated the existence of a single mechanism for the planet as a whole, including here the bio- and geosphere. Below we quote his own statements (cited from Balandin, 1982).

> The Earth's crust is for us an area of our planet that is exceedingly complex in its composition. . . . Its origin is unclear to us. Evidently, it is essentially strongly subjected to the permanent penetration of space radiations. It constitutes not an accidental group of phenomena, but quite a regular phenomenon in the history of the planet, a unique planetary mechanism. (p. 183)

Vernadsky goes even further: speaking of the evolution of folds in the brain and the Earth's crust, *he presupposes correlation between their evolution.*

13

There is a striking connection between the body size of different animals and their physiological and functional properties. It turns out that, proceeding from the allometric formula well known to biologists, it may be shown how different processes are affected in parallel by the change in body size (Peters, 1983). The book by Peters begins with a graph demonstrating the connection between the number of hours of daily sleep and body size in herbivorous mammals. The graph in the double logarithmic scale shows corresponding points grouping along the straight line: big animals sleep less than small ones. At the end of the book is a graph showing the good statistical coincidence between the predicted data and the observed ones for 68 functions setting the dependence of physiological functions on body mass. Note one unexpected conclusion: Rough calculations show that for warm-blooded animals "a full life is metered by each of 250 million breaths and 1.2 billion contractions of the heart" (small, short-living animals have a quick pulse, while the pulse of the elephant who lives more than 100 years is slow). Of interest are the ecological explications: the study of the links between population density of different animals and their body size. Parallel response to body size enables us to speak about the numerically measurable *similarity* in the living world (as a criterion of similarity we may naturally choose not only body mass but also other indices). How can this be explained from the conception regarding evolution as a random search on the field of discrete attributes (Beanbag Genetics approach)?

The above ideas of L. S. Berg on evolution as a convergence seems more plausible than those of Darwin on the convergence of the evolutionary process. A Bayesian model giving a single way of evolutionism again seems plausible.

14

The most debatable aspect of what has been said above is that the model in question ignores the creative role of natural selection. We are not in a position now to discuss a sufficiently controversial set of statements on the role of selection. I shall only mention a new idea related to the question of what the character of natural selection is determined by. According to Waddington (1976b), such a problem formulation generates a number of most interesting problems.

> In fact, a surprisingly large amount of the environment which exerts natural selection on an animal is the more or less direct result of the animal's own behavior. Quite often the animal has the choice that if he does not like it here he can go someplace else. Again, it is often the animal's behavior which decides whether he is selected for his ability to run away and escape from a predator, like a horse or an antelope, or for his ability to stand his ground and fight it off, like a buffalo, and, of course, the behavior which an animal will exhibit now must have been the evolutionary result of natural selection operating on his ancestors according to how they behaved in earlier periods. We have a typical cybernetic circularity of causation. . . .
>
> Once we consider evolution in terms of the selection of phenotypes which are produced by the development of a sample of genes drawn from a large gene pool, under the influence of an environment which is both selected by the organism and then selects the organism, we find ourselves forced to conclude that biological evolution, even at the subhuman level, is a matter of interlocking series of open-ended, cybernetic, or circular processes. (pp. 13–15).

The above assertions may also be interpreted as a recognition of the fact that some rudimentary forms of consciousness participate in the evolutionary process. Non-trivial expedient behavior of the entire population of animals under changing conditions is already a selection occurring on the unconscious level when in the behavior the change in the system of value concepts set by the Bayesian syllogism is realized in actions directly (without resorting to logic). Natural selection proves to be set in action by

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the same Bayesian spontaneity which is this time revealed on the field of value concepts.

In a purely logical aspect, the concept of natural selection in mutating self-reproducing populations is no more than the random search model. In this connection I direct the reader's attention to a short but extremely rich paper by Waddington (1968b) devoted to random search in biological evolution. He shows that there are many reasons to believe that this question can only be discussed in earnest for the evolutionary processes occurring on the *molecular level.* According to Waddington, matters stand differently with the evolution of higher organisms:

> In higher organisms it seems fairly clear that the changes which are evolutionarily successful are not in general dependent on single gene mutations resulting from random mutation. The great majority of random gene mutations which produce effects marked enough to be individually identifiable turn out to be harmful, and to be eliminated by natural selection. (p. 112). . . . we certainly do not have to suppose that a vertebrate eye, the leg of a horse, or the neck of a giraffe is in any important sense the result of random search. (p. 119)

Those statements have, indeed, much in common with Nomogenesis, to which our model is well adapted—there the concept of chance is no longer reduced to the random search model. It seems possible to speak of the hierarchy of chance corresponding to evolutionary processes of various degrees of complexity. However, we are not yet ready to discuss this question.

Geometrization of Biology

The well-known American physicist J. Wheeler formulated the famous slogan "Physics is geometry" (Wheeler, 1960; Angel, 1980). Indeed, many important physical problems involve consideration of the space metric.[14] Something of the kind may be observed now in biology. Modern biologists do not merely observe, as was the case in Darwin's time, but incessantly measure and calculate. Measuring, they do not consider their observation results separately, but by means of mathematics start analyzing a matrix—an image of a multidimensional space. The use of number leads to the geometrization of biology. There emerges a new biological reality, the spatial arrangement of the variety of life.

The model of global evolutionism proposed here again signifies the geometrization of biology: evolution is seen through probabilistic spaces.

[14]In the special relativity theory this is a non-positively defined pseudometric by Minkowski; in the general relativity theory gravitational potential is represented by a space-time metric tensor.

The book by L. L. Chislenko (1981) is actually nothing more than the geometrization of biosystematics.

Still earlier, at the beginning of this century, D'Arcy Thompson managed to show that the formation of shapes may be interpreted as a change in the metric of the space containing, if in a somewhat schematic form, a two-dimensional image of an animal. Figure 4 demonstrates how different forms of a crab's shell can be obtained from the initial one plotted on a uniform rectangular lattice by means of its compression or extension, using oblique or curvilinear coordinates. Figure 5 demonstrates various fish shapes obtained by analogous geometric transformations. Barger (1974) presented another picture of a similar spatial transformation of a two-dimensional animal image (Fig. 6). In the center of the drawing a pig is represented by a system of linear coordinates; in other coordinate axes it turns into a buffalo, a baboon, and some other unrecognizable animals that, though potentially possible, have not been realized in evolution. Barger's

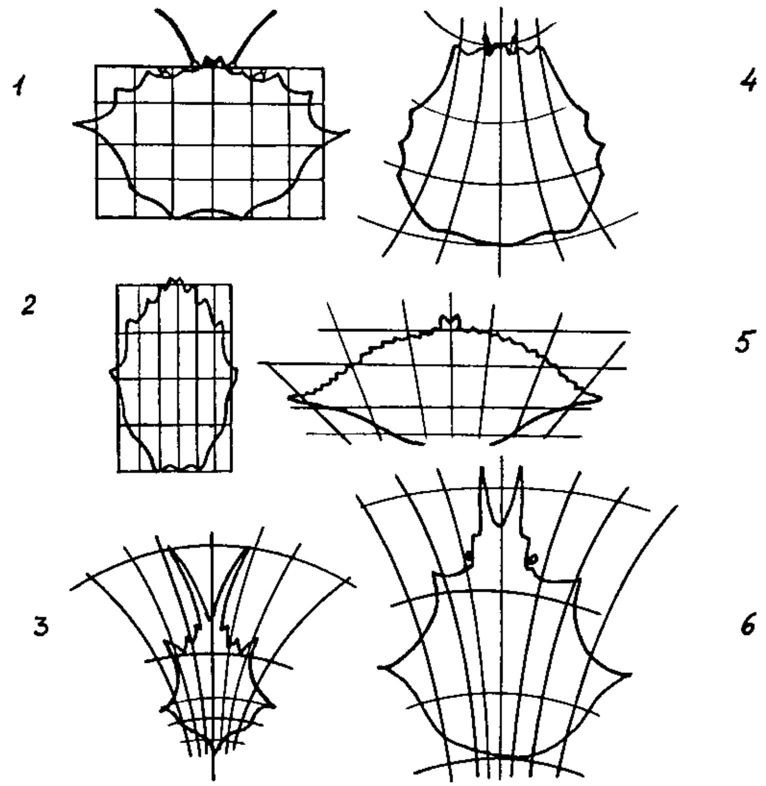

Fig. 4. Shells of different crabs: (1) *Geryon;* (2) *Corystes;* (3) *Scyramathia;* (4) *Paralomis;* (5) *Lupa;* (6) *Chorinus* (Thompson, 1942, p. 1057).

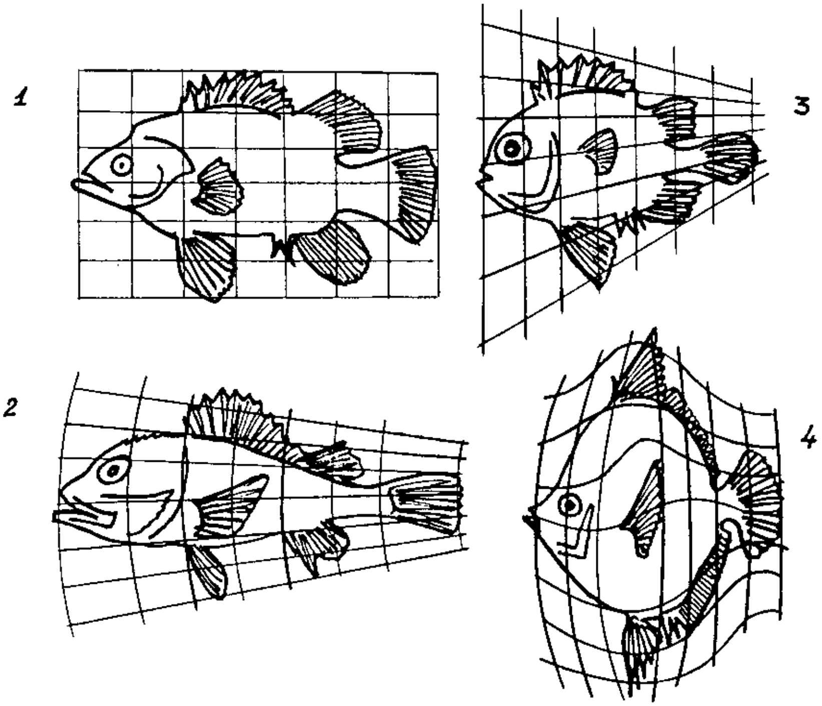

Fig. 5. Shapes of fish: (1) *Polyprion;* (2) *Pseudopricanthus;* (3) *Scorpeena* sp.; (4) *Antigonia capros* (Thompson, 1942, p. 1063).

drawing, demonstrated at a conference on high-energy physics, shows the art of playing with the rate scale of coordinate axes setting the metric of space.

Tracing the way started by D'Arcy Thompson, I should mention the book by Bookstein (1978),[15] a recent article by Todd et al. (1980), and, finally, a book by the Soviet biogeometrician S. V. Petukhov (1981) where the major attention is paid to conformal (circular) symmetries and the so-called Fibonacci numbers in biological bodies, in particular, in the kinematic scheme of human and animal bodies. The concept of the non-Euclidean basis for the morphogenetic laws acquires fundamental significance. Especially interesting in the book by Petukhov is the search

[15] Here is how Bookstein (1978) formulates his task:

> . . . we know that shape, however measured, is biologically real and relevant, just as are yields and gene frequencies and evolutionary trees. (p. 3)
>
> I intend a thoroughgoing redefinition and reconstruction—the measurement of shapes, their variation and change—as a branch of applied modern geometry. I will try to set up geometrical formalizations of shape which can serve as frameworks for quantification, for measurement of actual shape phenomena. (p. 2)

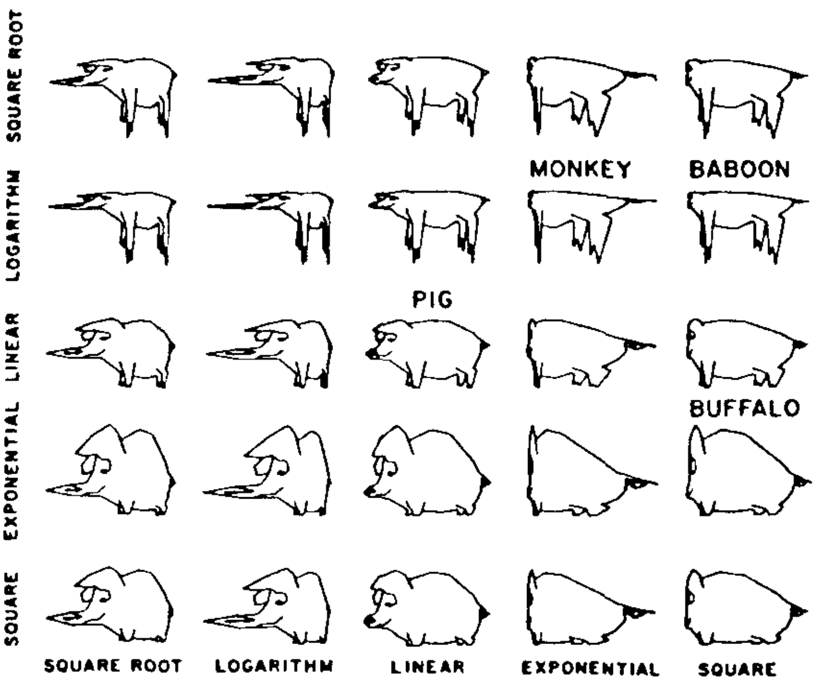

Fig. 6. Geometric interpretation of phenomenological changes (Barger, 1974).

for projective symmetries in the position of the five extreme points of the human body. It turns out (Fig. 7) that the ontogenetic transformation of body geometry preserves the same penta-symmetry that occurs in five-petal flowers, in the bodies of star-fish, etc. Petukhov emphasizes also that, as the organism matures, the center of bodily ellipses shifts from the navel to the genitals, and asks whether this geometrical shift is of any significance. It follows from the figure that the pentasymmetric transformation[16] may also be interpreted as transformation conditioned by the change in metric of the space in which the shape is given.

Now let us return to the problems that emerged when biologists started to resort to computer analysis of multidimensional data. The questions that arise here are quite serious. What is the structure of a biological space proper; i.e., what is its metric? Carrying out a multidimensional analysis of data, can we proceed from the single, biologically grounded metric space structure or should we infinitely vary the choice of metrics proceeding from heuristics? How should the variables be transformed? Shall we resort to conjugate transformations of the variables, e.g.,

[16]Earlier (Nalimov, 1982), I spoke about the role of a five-edged star in a culturological aspect. Perhaps, the mythology of a pentagram was generated by the observations of ancient geometricians concerning the process of man's growth.

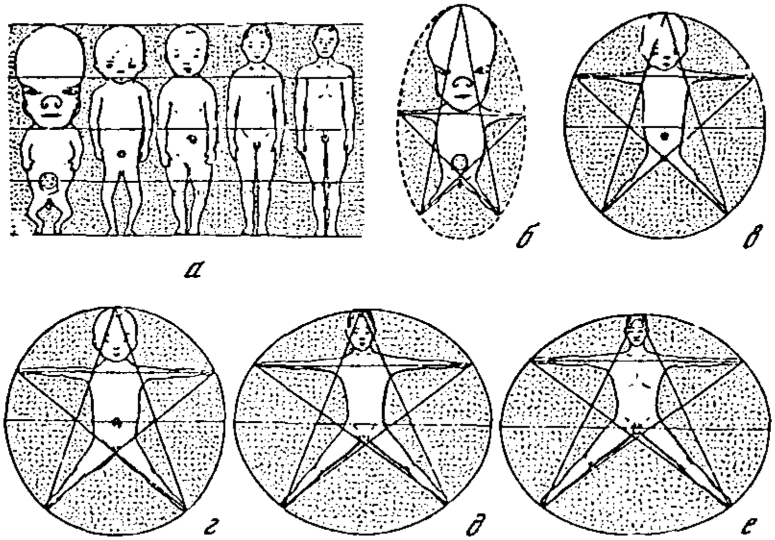

Fig. 7. Ontogenetic changes in human body in the erect posture (a) and spread (b–f). (a) From left to right, a two-month embryo, a four-month embryo, a newborn child, and six-year-old and twenty-five-year-old persons (borrowed from B. M. Pattaye, *Human Embryology*, Moscow: Medgiz, 1959). (b) A two-month embryo. (c) A four-month embryo. (d) A new born child, (e) A six-year-old person. (f) A twenty-five-year-old person (Petukhov, 1981, p. 120).

dealing with quantity and biomass to pass to their ratio or to extracting the square root from their product? Is it reasonable to pass from the directly measured variables x_i, x_j to the parameters relating them to the formula of allometric growth

$$x_i = ax_j^b$$

Parameters a and b can be regarded as new, indirectly measured variables. They still seem to have a clear-cut biological interpretation.[17] It is also possible to ask: how can biological time proper be geometrized and what is its relation to astronomic time? Those problems are new for biologists. In a general theoretical aspect they may be regarded as a direct sequence from representing evolutionism by the Bayesian syllogism. However, from the practical viewpoint we should not forget that they emerged as a result of the contact between biological science and computer

[17]Korostyshevskii and Eppel (1979) note that the parameter b is a relation between the sensitivity of subsystems x_i and x_j to control, whereas the parameter a depends on the initial conditions, i.e., on the relation between subsystems by the moment of formation in ontogenesis of the control structure. However, we should always take into account the fact that the law of allometric growth is only given by approximation formulas.

technique. It must be emphasized that if the problems formulated here are not solved, if the nature of a bio-space is not comprehended, then biologists' contacts with computers will have only arbitrary, and sometimes even meaningless results. It is noteworthy, that here for the first time we approach the philosophical problem of the role of an observer in biological research. Biological space seems to be the new biological reality that does not exist as it is; it only emerges as a result of interaction between the researcher and nature. Here arises a certain remote parallel with the ideas on the role of an observer in modern physics.

Our metric approach to the geometrization of biology may be historically opposed to the well-known approach of Rashevsky.[18] Considering the possibility of constructing a theoretical biology as an abstract discipline, he turns to topology, assuming that the typical feature of organization in animate nature, in contrast to inanimate nature, is not metric relations, but continuous transformations of objects into one another (Rashevsky, 1954):

> While physical phenomena are the manifestations of the metric properties of the four-dimensional universe, biological phenomena may perhaps reflect some local topological properties of that universe. (p. 317)
>
> The topological spaces or complexes by which different organisms are represented are all obtained from one or at most from a few primordial spaces or complexes by the same transformation, which contains one or more parameters, to different values of which correspond different organisms. (p. 325)

However, as was rightly noted by Akchurin (1974), in such an approach there arises a difficulty connected with the necessity of rigid geometrical localization:

> . . . in the science of animate nature, such a seemingly "innocent" assumption as a commonly implicit hypothesis of the representability of all objects of the theory by sets almost automatically leads to rejecting such a determinant feature of the living world as freedom, unpredictability of actions and replacement of a biological creature by a rigidly determined scheme. (p. 109)

Almost simultaneously with Rashevsky, his pupil Rosen started to develop an even more refined approach. In his first paper (Rosen, 1958a), he applied topological considerations to the organism as a whole [an interesting analogy to it is a paper by Rashevsky (1958)]. In his next paper,

[18]Rashevsky connects the development of his conception with the above-mentioned paper by D'Arcy Thompson (1942) as well as fairly general considerations developed by Kurt Lewin (1936).

Rosen (1958b) introduced the concept of an abstract biological system with an entrance and an exit. Such systems include both an organism and its organs. Elements of these systems respond selectively to each entrance. Proceeding from the mathematical theory of *categories and functors,*[19] Rosen considers several aspects of the general theory of biological systems: his approach is close to the general theory of automata.

I am not in a position to go into details concerning further evolution of Rashevsky's and Rosen's ideas. The papers by Rosen are reviewed by Roschin (1982) in the book by Levich (1982); the bibliography to this book contains a list of publications by Rashevsky and Rosen devoted to an attempt at a mathematical comprehension of theoretical biology. As far as I can judge, their approach remained foreign to biologists. In any case, their names are not mentioned in the well-known book by Mayer (1982), whose aim was to give an all-round review of the evolution of biological thought, and I did not find references to them in the volumes of *Towards a Theoretical Biology* edited by Waddington (1968, 1969, 1970, 1972). Still, we should emphasize the idea expressed by Rashevsky (1956) that it was the geometrization of physics that opened up the prospects for the geometrization of biology. In his later work Rashevsky (1967) removed the sharp opposition between comprehending the problems of physics, on the one hand, and those of biology and sociology, on the other hand.

Geometrization always consists of reducing the concepts about the World to geometric localization. The history of physics is to a certain degree that of modifications of the notion of localization. Classical mechanics dealt with a Cartesian spatial localization point moving in time. The introduction of field concepts into physics brought about the concept of continuous spreading in space of a physical index. In the microworld localization is no longer fixed rigidly (Heisenberg's uncertainty principle, Schrödinger's equation). In modern physics, one observes the tendency to deepen the concept of localization by introducing *topos*—spaces with a fluctuating topology: the vicinity of the point becomes variable. In our formulation of the problem, we made use of a probabilistic space, which changes radically the concept of localization. The morphophysiological field contains everything, but this everything in different parts is ascribed different measures related by the normalizing condition. To be localized in the probabilistic meaning is to have a measure of localization. What I have in mind is not fixing localization by the binary relation *yes–no,* but the manifestation through a measure of what is eternal, extra-temporal.

[19]Category and the related concept of functor belong to modern algebra and are applicable to other sections of mathematics. Category is an area of mathematical speculations in which there is a conglomerate of objects (e.g., arbitrary sets) such that together with each pair of objects A and B it contains the conglomerate of morphisms from A and B. Morphisms may be arbitrary mappings of one set into another. Functor is a transition from one category into another during which identities and the composition of isomorphisms are preserved.

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Everything exists in the measurable manifestation of the entity. Hence the flexibility in the description of the evolutionary process that we try to demonstrate. It is generated by the easiness of measure variance that is allowed for by the concept of a probabilistic space. It is due to this flexiblity that my approach removes all the troubles accompanying the rigid localization in Rashevsky's geometrization emphasized by Akchurin.

Internal Biological Time as a Measure of Changeability

We have learned a lot by simulating ecosystems under the conditions of a powerful anthropogenous influence: quasievolutionary processes are now taking place in front of the researchers' eyes. It has become obvious that the state of a system may change in leaps. A biological space–time manifold is seen as non-differentiated or at least locally non-differentiated, which accounts for the irrelevance of simulation by means of differential equations. These ideas have much in common with paleontologic observations. In the words of S. V. Meyen (1981), ". . . studying the past of the Earth, we are practically without a clock" (p. 150).

Further, he maintained that we can make judgments about geological time by proceeding only from the changeability in the objects under study but

> . . . the observer notes that the changeability of objects is different since the processes occurring to objects are different. According to the classes of objects, classes of processes can be selected, and therefore classes of time as well. (p. 151)

Note also the assertions by V. I. Vernadsky on the polymorphism of time. They are clearly formulated by Balandin (1982):

> He held that in the life of the Earth Life manifests itself in three ways. Above all, it is apparent in the radioactive processes of decay of atoms. This may be referred to as the time of destruction.
>
> In many processes there are inherent turnovers, i.e., perennial returns to the initial state. This is a kind of rotation of time.
>
> Lastly, time is manifested absolutely differently in the evolution of living creatures, the appearance of more highly developed, more "intelligent" species. This is the time of creation and development.
>
> It turned out that under natural conditions time—if taken as a symbol and index of variation—moves in a fancy manner, depending on the object at hand. Each object, in essence, has its own time, or strictly speaking, constitutes a kind of clock. (p. 93–94)
>
> But what is time in general and geological time in particular? (p. 179).

> Vernadsky frequently wrote about the unity of space-time: each type of space possesses its own time. *In other words, each geological object has its own time scale.* (p. 180)

It seems relevant to quote here a short statement by Pattee (1968a) on the peculiarities of biological time.

> *Multiple time scales are certainly a crucial aspect of life.* Physics commonly uses only one time scale (except in some non-linear thermodynamics). . . . For example, there is physical time as in the equations of motion, there is catalytic time which may be necessary to describe enzymes, there is cellular reproduction time, there is organism development time, there is individual generation time, there is ecological succession time, and finally there is evolutionary time. Perhaps psychological or conscious time should also be added. (p. 219)

I shall not consider here either the attempts to give an experimental definition of different modes of biological time, or the attempts to comprehend theoretically the nature of biological time. A thorough consideration of these questions would make us touch on the philosophical aspects of time, which is an extremely complicated and extensive problem. [Earlier (Nalimov, 1982), I considered the question of a personal, physiological time, and in this connection touched on the general philosophical problems of time.]

I shall consider only the new comprehension of biological time that follows from my ideas on the metric geometrization of biology.

Making an attempt to explain such phenomena, we may introduce the concept of internal time t as a scalar field given on the multidimensional space of attributes $\mu_1, \mu_2, \ldots, \mu_N$. The rate of change of the field in some direction μ_i will in the simplest case be given by the particular derivative $\partial t/\partial k_i\mu_i$, where k_i is a parameter characterizing the expansion of the scale μ_i. Possible discrete changes in the numerical values of k_i will lead to a change in the rate of internal Time; e.g., making k_i tend to infinity, we shall effectuate the second passage to the limit and obtain zero rate of internal time (if the derivatives are finite in *all* points). Changes in the distribution functions occurring in the Bayesian syllogistics may be interpreted as the local changes in the metric of the scales on which the distributions are given, and therefore it is possible to speak of a change in the rate of internal time (in the general case, non-linear local metric transformations should, of course, be considered, proceeding from the idea of the existence of metrically heterogeneous spaces). Otherwise, time proves to be multidimensional for one spatial axis. Thus, it is possible to introduce the concept of multiple time and its potential leap-like change responding even to a local evolutionary impetus. Time proves different for each direction in the space μ; moreover, it may also be different in different parts of each

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direction. Hence, it follows that it cannot be correlated with astronomical time. It remains unclear whether the concept of internal Time can be made so concrete as to make it measurable. In any case, now it would seem natural to treat with extreme caution dynamic imitation models of ecosystems proceeding from the *a priori* notion of the existence of homogeneous dynamic time commensurable with astronomic time. It is natural to give the preference to multidimensional pattern-analysis (as applied to the multitude of different metrics) setting only individual time environments of the system. I came to the same recommendation earlier (Nalimov, 1983) from different considerations.

Note also that I introduce the idea of the time rate without introducing, as it is common to do, the idea of the two-dimensional nature of time in order to be able to take the derivative dt_1/dt_2.

Traditionally, we proceed from the idea that the course of time determines the order of events. In my model, the spontaneous emergence of the evolutionary impetus determines the state of proper biological time. If, for example, a sequence of evolutionary impetuses is of a regressive character, i.e., leads anew to the emergence of an ancient form, this can be regarded as the closure of time: the rates of personal times become such as they were before—the past (that has already disappeared) merges with the future (evolutionary impetus always consists in choosing from the future as a potential variety).

Model of Global Evolutionism as Illustrated by the Evolution of the Texts of Culture

Global evolutionism allows us to regard the evolution of culture from the same standpoint as that evolution of the living World. The evolution of culture consists in revealing the meaning through texts. Production of texts and their understanding is always connected with the evaluation of meaning. On the discrete, logically structured level, such evaluation is made by means of formal logic based on some initial premises. On the deep level of consciousness, the meaning is evaluated on the semantic continuum in accordance with the Bayesian syllogism. What happens is pre-thinking,[20] the change of significance of the initial premises. Thus, pre-thinking predetermines the process of logical thinking. It is possible to regard from

[20]We proceed here from the idea of the triple structure of human consciousness. Its upper level is *thinking proper* realized by means of Aristotelian logic, and always based on some premises. The latter are elaborated on the level of *pre-thinking* governed by numerical logic and where, in accordance with the Bayesian syllogism, different segments of the semantic field are ascribed different weights; segments with great weights are reduced to discrete meanings and become premises for logical thinking. The lowest level of consciousness is the *cellar of consciousness* where it interacts directly with the semantic field of the Universe through a system of archetypic symbols. Here scripts are performed and experienced that are revealed to us only through meditation.

this standpoint the evolution of texts of culture, the creative process of a scholar, the change of paradigms in science.

Earlier (Nalimov, 1982), I spoke of the evolution of a personality. The change of *Ego* consists in constructing the system of value concepts $p(\mu)$ in a new situation y, brought about by the spontaneously emerging filter $p(y \mid \mu)$. Here again, the Bayesian syllogism enters the game. A tragic event in human life or society plays the same role that a sharp change of the environment does for the species of flora and fauna. In both cases it is necessary to adapt to the aggravation of the situation. But humans, like the biosphere, are also capable of preadaptation. On the deep levels of their consciousness, people foresee the forthcoming events and get ready for them by changing their value concepts beforehand. This is the only way to explain the advent of revolutions. Value concepts of so many people prove to have changed so radically that it opens up the possibility of a new, unprecedented wave of events. This wave was merely unthinkable in the former paradigm of society. Perhaps the major peculiarity of the animate world, its principal difference from the inanimate one, is the presence of the elements of the Future in the Present.

Speaking about the evolution of culture, we shall have to consider the change of the system of value concepts $p(\mu)$ related to the entire culture. Each culture, according to our conception, has a value dominant, a *paradigm* representing a fuzzy field of value concepts over which the probability distribution function is given. Side by side with the dominant paradigm there exist sub-paradigms, often in the underground of culture—they are sprouts of the future. Earlier (Nalimov, 1982), I spoke of a personality as a multidimensional structure [what psychiatrists call "multiple personality" (e.g., Bearhs, 1982)] composed of correlated constituents; the same is, perhaps, true of culture as a whole. It is also possible to speak of a hyperpersonality—a model of interpersonal relations emerging when personalities (two or more) behave as one, i.e., when their systems of value concepts are for some time correlated. A similar model may be correct for a culture, too, but this seems to be a problem of the future, though in the remote past, the Mediterranean world acted as a hyperculture composed of its correlated constituents personified in various peoples and various regions of the contemporary World.

From the Bayesian model it follows that the evolution of culture, like biological evolution, may prove to be submerged in the single stream that, being generated by a single new filter $p(y \mid \mu)$, will embrace not only the major paradigm of culture, but its constituents as well.

Consider the emergence of Christianity as an illustration. It sprang from the system of value concepts of Judean culture expressed verbally in the Old Testament. There occurred an evolutionary impetus: distribution function $p_1(\mu)$ setting the initial value concepts is transformed into a new value orientation $p_1(\mu \mid y)$. If the New Testament, and especially the first three synoptic Gospels, are analyzed thoroughly, we see clearly that the Old Testament paradigm is preserved there as a background; on this background there emerge problems acquiring the new meaning that is usually opposite to everything preceding it, which we identify with Christianity. However, the past is always there. Its significance is heterogeneous: some features of the past are almost completely suppressed; others are preserved in their full significance. The same evolutionary impetus affected another Mediterranean sub-paradigm $p_2(\mu)$ otherwise philosophically oriented, the one that was under great influence of Oriental thought. Thus appeared the gnostic Gospels directed at the philosophical–mythological interpretation of the World; close to the Oriental *Weltanschauung*. The connecting link between these two trends was the fourth Gospel essentially different from the synoptic ones.[21] Two systems of concepts generated by one evolutionary impetus could not coexist. Gnosticism was suppressed in the first ages of the Christian era.[22] The inclusion of the fourth Gospel into the canon was debatable at one time. From the point of view of culturology the most interesting fact is that for the sake of strengthening the value orientation $p_1(\mu \mid y)$ the Bible, the basic Christian text, was made to include, side by side with the New Testament, the Old Testament based on the initial value orientation $p_1(\mu)$, despite the fact that from the viewpoint of formal logic those two texts contain a lot of opposing statements. However, the Bayesian logic indicates that there *was* ground to unite them under one cover. It is also noteworthy that the discussions are still going on as to how gnosticism was born: one viewpoint is that it had emerged before Christianity. We might agree with this viewpoint if we believed that Christianity had also appeared before Christ. The annihilation of gnosticism and the triumph of Judeo-Christianity were the outcome of natural selection. The first of these trends, from the philosophical point of view, proved to be too refined and too incapable of compromise—it was not able to adapt to the surrounding intellectual–psychological environment of the Mediterranean. Manichaeanism, one of the gnostic trends, spread far to the East, but this did not, in the long run, provide its survival, though it existed much longer than other gnostic trends (it was completely forbidden in China at the end of the fourteenth century). It seems relevant here to draw a parallel with the above-quoted words by Waddington that natural selection even in the biosphere includes decision-making: such a decision may concern the change of the area.

Nowadays, too, we may trace the existence of the same Bayesian stream in the evolution of culture. Recall our recent past. We can obviously

[21]The opposition between one of the canonical Gospels and the rest is distinctly given by Burtt (1964). (For an excerpt, see Nalimov, 1982, p. 127.)

[22]Almost all the texts were destroyed, and for a long time they were known only from refutations; then suddenly the recent discoveries provided us with the orignal texts.

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trace there internally close but outwardly alienated trends of thought: positivism, the optimism of classical physics, Darwinism, Freudianism, and behaviorism. They all developed on the foundation of a deep belief in the omnipotent formalism of logic, in the simplicity and mechanisticity of nature and the omnipotence of its laws (one only had to discover them), in undoubtful tangibility of matter and absolute nature of space and time. However, the old trend was not yet exhausted when a new wave of thought sprang up: physics generated the idea of uncertainty and non-locality (in quantum mechanics) and the probabilistic element was strengthened; the conception of the existence of elementary, indivisible particles of matter became loose; the self-evidence of space and time disappeared; Gödel's theorem had a broad influence in physics and mathematics; psychology developed a new, though not universally acknowledged, *transpersonal* trend; science agreed to recognize the complementarity principle; philosophy was tempted by the problem of existentialism. There emerged a profound interest in ancient philosophical ideas of the East, displayed even by physicists. And if we ponder over all these so different manifestations of our modern thinking, we shall easily notice the new value orientation uniting them all, though it is sufficiently fuzzy and is therefore hard to formulate. Thus, the paradigm of our time started to take shape. It represents again a broad stream embracing different trends of thought. Under its cover we feel a completely new, still obscure roughness of ideas. But the old paradigm is still strong in many points. We are living in a World of two overlapping paradigms.

Philosophical and Methodological Interpretations of the Model

1

Evolutionism understood on the global scale requires introduction of the notion of the *spontaneous* emergence of new information. Spontaneity is viewed as an unpacking of what nature potentially contains, this unpacking not being conditioned by cause-effect relations though including elements of necessity. Spontaneity is manifested through measure. Recorded by means of the Bayesian syllogism, it helps us to make our conception of the role of chance in evolution more profound. It may be regarded as another approach to the principle of *emergence* discussed earlier in the literature (Pap, 1951). The conception of the spontaneous emergence of the new information might as well be called the faculty of the system for *self-transcendence;* terminological enrichment of the conception always makes its comprehension more profound. In any case, this is what

Jantsch wrote on this point in his preface to the well-known book *Evolution and Consciousness* (Jantsch and Waddington, 1976):

> . . . the contributions to this book try to develop a new understanding of an evolving world of human systems which are characterized by the same aspects of imperfection, nonequilibrium, and nonpredictability, of differentiation and symbiotic pluralism, which seem to govern life in all its manifestations. They argue that the human world, analogous to physical and biological evolution, incorporates a basic principle of *self-transcendence,* of venturing out by changing its own physical, social, and cultural structures—above all, by changing its own consciousness. (p. 2)

It is noteworthy that Waddington, the second editor of the above book, in his speculations resorted to a linguistic metaphor (just as I do):

> Biological systems, in their genetic and evolutionary processes, transcend themselves in a way comparable to that in which a natural language can discuss its own structure (and becomes in doing so a metalanguage), a possibility which is not open to completely formal languages. Pankov speaks of this additional phase of self-transcendence as a form becoming a "gestalt." A similar point was made, particularly by Howard Pattee, during a series of discussions on theoretical biology which I organized a few years ago at the Villa Serbelloni in Italy. There the notion was put most aphoristically by pointing out that we regard certain biological molecules as messages; that is to say, we consider them as conveying instructions of a kind comparable to the instructions which can be given in a natural language. I am sure that this is an extremely important manner of regarding living things and their evolution, but I think it still needs a great deal of further working out, both as to its biological basis and its consequences. I confess that I am not at all clear about the relations between sets of instructions in general, those sets which may lead to deviation-amplifying systems, and those which give rise to the self-transcendence characteristic of natural languages. But we are certain that at least some sets of instructions can achieve this transcendence, so we can perhaps leave it to the professional philosophers to decide what characteristics these sets must necessarily possess. (p. 248)

Further, Waddington strikingly passes to the necessity of introducing the concept of value:

> Instructions are necessarily instructions to behave in certain manners, that is, to alter things in some way or other. Any alteration of a situation must always have a characteristic corresponding to a "value" for *some* system of assessment; for instance, a genetic change of instructions for the synthesis of a particular protein, or for carrying out a

particular type of behavior, will have value from the point of view of natural selection. This leads to the conclusion that the expression of specificities in terms of instructions necessarily involves us in normative thinking.

Since all biological systems contain a multiplicity of instructions, it seems natural, if not inevitable, that they will be involved in a multiplicity of value systems. (p. 249)

It seems that there is only one step from these statements to a Bayesian model.

Still, no matter what metaphhor we choose to describe evolutionism, there is always a question: what are we ready to give preference to—the creative dominant smoothed down by the mechanistic influence of the environment or the purely mechanistic dominant in the process of emergence and evolution of the new information.

My approach is obviously opposed to the mechanistic dominant that was lately most spectacularly expressed by Prigogine, on the one hand, and by Eigen, on the other hand. Both scientists are Nobel prize winners in physics.

Prigogine's conception devoted to thermodynamic explication of evolution was rather thoroughly described in *Evolution and Consciousness* by Taylor (1976):

> The new field of nonequilibrium thermodynamics has postulated the principle of "order through fluctuation" whereby such systems, being partially open to the inflow of energy (information) and/or matter, develop instabilities which, however, do *not* lead to random behavior (even if the initiating fluctuations as such are random). Instead, they tend to drive the system to a new dynamic regime which may correspond to a new state of complexity. Nonequilibrium systems are characterized by a high degree of energy exchange with the environment (and can therefore be termed dissipative structures). Thus, nonequilibrium dynamics is moving toward a theory of self-organisation of processes and structures, applicable not only to the physical but to the biological and social domains as well. (p. 176).

Prigogine (1976), in the conclusion of his paper, makes the following assertion:

> Bergson . . . made the following statement: "The further we penetrate the analysis of the nature of time, the more we understand that duration signifies invention, creation of forms and the continual elaboration of what is absolutely new."
>
> We recognize that we are beginning to clarify these notions of "invention" and "elaboration of what is absolutely new" by the mechanism of successive instabilities caused by critical fluctuations. . . . The

discovery of such mechanisms, which play such an essential role in a vast domain stretching from physics to sociology, is obviously a preliminary step toward some harmonization of the points of view developed in these different sciences. (p. 126)

Of interest in Prigogine's paper is the paragraph where the process of building termite nests is simulated (using differential equations with partial derivatives). It is shown how order may emerge from disorder. However, the words *may* and *must* have different modalities. And while from the contemporary non-equilibrium thermodynamics it follows that order may emerge from disorder, this is not to say that the hereditary order should produce (with a sufficiently high probability) the striking harmony that we observe in the living World, because what we keep in mind is harmony, not merely complexity.

And now a few words on Eigen's conception. In contrast to my approach, his viewpoint is that evolution is not an unpacking of words but their accumulation (Eigen and Winkler, 1979): "The evolution of the biosphere is a majestic process of accumulation of information and memory formation" (p. 90). According to Eigen, the information accumulation in living self-organized system is underlain by a purely physical principle. The individual evolution being indefinite, the faculty to evaluate the stimuli coming from the environment is built-in. And the faculty of selective evaluation is the way toward creation of new semantics. Eigen's main idea is best formulated in the words concerning the notion of freedom (Eigen and Winkler, 1979):

Individual freedom is the functioning of a filter localized within a personality. The filter is composed of heredity, experience, and the faculty to make evaluations implied in the system. It is overlaid by statistical fluctuations governed by stimuli and its output is "information" in the form of our ideas and thoughts. (p. 91)

In my conception of freedom (Nalimov, 1982) I also make use of the notion of a filter. It is represented by the function $p(y \mid \mu)$ spontaneously arising in a new situation y. According to the Bayesian syllogism, the filter affects the former system of value concepts $p(\mu)$ reflecting the entire preceding experience. Within our system of views, freedom is not reduced to game fluctuations and, correspondingly, *creativity*, no matter where it is realized—in human consciousness or in the evolution of the animate world—is not reduced to the process of selecting from what is produced by purely mechanical game processes that are a constituent of Eigen's conception. The faculty of evaluating information coming from the environment assumed by Eigen is actually a very strong assumption, but is it sufficient?

2

Resorting to spontaneity has proved to be a convenient means for a delicate description of evolutionism as a *creative* process. I am quite aware of the risks of including the creative element in the evolutionary process. However, without that, the description of evolution will always remain deficient. The important thing is to display a sense of proportion. In this connection I quote from Elsasser's (1968) brief conclusion to the first volume of *Towards a Theoretical Biology:*

> I think the main problem in this connection when it comes to biology is the perfectly valid objection made by many people against Darwinism, that ultimately evolution must include some form of creativity. But Henry Bergson made a colossal blunder when he tried to introduce the concept of creativity, which ought to remain metaphysical, directly into his discourse. I have tried to avoid this carefully by reformulating biology on introducing "unanswerable question" instead. This is a little bit after the manner of the philosopher Wittgenstein, who once said: "Where there is no answer, there is no question." (p. 221–222)

I have tried to avoid the inadvertency of Bergson (1913) by introducing the notion of a creative element in an abstract, mathematical form. To underscore the contrast, I quote the following lines from Bergson (1913):

> Organic *creation,* on the contrary, the evolutionary phenomena which properly constitute life, we cannot in any way subject to a mathematical treatment. (p. 21)

At the same time, there we come across a brilliant definition of creativity:

> The impetus of life, of which we are speaking, consists in a need of creation. It cannot create absolutely, because it is confronted with matter, that is to say with the movement that is the inverse of its own. But it seizes upon this matter, which is necessity itself, and strives to introduce into it the largest possible amount of indetermination and liberty. (p. 265)

I do not answer the question of what a creative element is, but I believe that it may be discussed in the language of symbolic structures. The essential thing about the structure of science is that it does not reveal what I am ready to call (following Tillich) the *ultimate reality.* It only gives an outline; it becomes an image hardly discernible in the fog of our structures. Such images used to emerge in past cultures but they do not suit us any longer. An image of something that is not grasped conceptually but is slightly delineated always provokes our thought.

3

If we are ready to ascribe the status of biological reality to the space of morphophysiological attributes, then it is natural to assume the dynamic nature of this space geometry.[23] This dynamical nature may be described in two ways: (1) proceeding from the concept of local fluctuations in the distribution functions; (2) directly in terms of local (i.e., spatially limited) fluctuations of the metric of morphophysiological space. The two descriptions are in some sense equivalent. Bayesian evolutionism, much spoken of above, may be considered as nothing more than a convenient way of describing the directed and sufficiently complicated local metric changes that cannot be described without resorting to a probabilistic measure. What we must keep in mind is the possibility of describing the same phenomenon in two geometric languages. We shall not be confused by the fact that the passage from one to the other may be approximate.

4

Stochastic dynamics of a morphophysiological space seems to explain the phenotypic (not inherited) interspecific changeability called *modification.* This needs, perhaps, some biological comments. Not being a biologist, I shall confine myself to quoting the assertion of the geneticist Golubovskii (1982) made in connection with the views of Lubishchev:

> At the lowest interspecific level of evolution the manifold becomes limited (ordered). Later, after Iogansen's experiments the "omnipotence" of natural selection had to be limited. Individual deviations (modifications) turned out not to be inherited and the selection is efficient in a population until the hereditary heterogeneity is not exhausted. Despite the phenotypic changeability, in pure lines, the selection does not yield any results. On the other hand, H. de Friz showed that hereditary changes, mutations, distinguishing one species from another, emerge outside the range of selection, but by means of accumulating small adaptive deviations, as Darwin had postulated. (p. 59)

My model contains the idea of all three kinds of changeability. On the one hand, we have here the difference in distribution functions $p_i(\mu)$ determining the interspecific hereditary heterogeneity; on the other hand, there is a not inherited phenotypic modification $d_i(\mu)$ caused by spontaneous fluctuations of the metric of the morphophysiological space preserving its significance only during a lifetime of an individual. And, finally, there is the third kind of changeability related to the emergence of essentially new information $\hat{p}(y \mid \mu)$.

[23]My speculations are somewhat analogous to Wheeler's conception of geometrodynamics of the physical space. I shall speak of Wheeler's conception in detail below.

Golubovskii drew our attention to the fact that genetic systems are built according to the following principle: *the unity of the whole and freedom of its constituents.* We may believe that the unity is set by the function $p(y \mid \mu)$, and freedom is set by the variety of the functions $p_i(\mu)$ affected by it.

5

A probabilistic comprehension of the nature of changeability in a surprising way includes the principal philosophical idea of Darwinian evolutionism. Lewontin (1974) stated that Darwin made a decisive step, having rejected the Plato-Aristotelian essentialism according to which all objects were regarded as imperfect reflections of the principal, ideal essence. Strictly speaking, before Darwin, we could speak not of evolutionism but only of transformism: of a transformation of a taxon of one type into another. Darwin developed the idea of evolution as a process brought about by the changeability of individuals (Lewontin, 1974): "Darwin's revolutionary theory was that the differences between organisms within a species are converted to the differences between species in space and time" (p. 170).

The Bayesian concept of a species as a bound totality of non-identical but close species requires a more sophisticated model of continuum unpacking. For example, for a species consisting of n individuals, the model will be represented by an n-dimensional distribution $p(\mu_1, \mu_2, \ldots, \mu_n)$. The evolutionary impetus affects each individual separately, since each of them is set by its own initial distribution function $p(\mu_i)$; but after the evolutionary impetus, individuals that are correlationally close may remain within one species. The split of a species may be regarded as a process of orthogonalization. For example, it can be easily shown that in the simplest, two-dimensional normal distribution, orthogonalization is achieved by a suitable turn of coordinate axes. Thus, the purely geometric approach to species formation becomes possible.

6

A profoundly abstract, symbolic description of evolution preserves biology in the status of a descriptive science, irreducible to physicochemical phenomena. My work may be regarded as a response to the call by the well-known Russian hydrobiologist G. G. Vinberg (1981) to produce a mathematical model so polysemantic as to be able to reflect the manifold of life manifestations:

> . . . This polysemy reflecting the manifold manifestations of life and their dependence on the environment hinders formalization of biological

> concepts necessary to enable the application of mathematical methods, a formalization that would not oversimplify and thus impoverish their contents. Such hindrance should be realized and overcome by elaborating mathematical structures adequate to the biological systems. . . .
>
> Due to the specific objects of biology—each of them is an irreproducible and unique result of the adaptive evolution—and to the pecular methods of research with the dominant position occupied by descriptive methods, as is shown above, theoretical biology essentially differs from theoretical physics and other science of living nature. . . .
>
> The simplified idea of the methodology of biology, ignoring its differences from that of the inanimate natural sciences, hampers the proper organisation of biological research and the creation of new methods, including here mathematical ones which would be adequate to the specific peculiarity of the living world, namely, the variety of life manifestations. (pp. 10–12)

My answer to Vinberg is that a mathematical model retaining the descriptive nature of biological science and reflecting the entire variety of life manifestations may be constructed as a measure arranged into a probabilistic space. But will a biologist be happy to have such an answer?

7

Note that, when we resort to the idea of shape formation as unpacking of the morphophysiological continuum, we merely make an attempt to find an image for the potential shape responsible for ontogenesis. Up to now no general theory of ontogenesis has been created (Golubovskii, 1982a). Here we seem to follow the road outlined by Lubishchev. According to the Russian genetist Golubovskii, Lubishchev regarded a gene primarily as a potential shape:

> Lubishchev shows that the introduction of the notion of a potential shape, even as a scientific fiction, will allow us to free ourselves from the narrow mechanistic conception and will provide a theoretical basis for the mathematical approach to morphology and morphogeny. (p. 59)

What can we say about the nature of a morphological continuum? It would seem rash to believe that this is nothing more than a logical construct. Human consciousness had produced refined geometric structures to comprehend both the World and itself. Why shouldn't we then assume that nature itself generating a variety of shapes—purely geometric structures—is not based on the geometrically given potentiality?[24]

[24]Another geometric property of the world was discovered by Pasteur: differentiation of optical isomers by means of microorganisms metabolizing only one of them.

My ideas of the morphogenetic continuum have much in common with the words of Lewontin, the well-known evolutionary biologist, on the inconsistency of discrete notions in genetics. Discussing the question of dimensions of the evolutionary space, Lewontin (1970) wrote:

> Now, however, we wish to claim that the number of loci is irrelevant and even, in a sense, meaningless. If the chromosome is to be treated as a continuum, then chromosomal "types" are no longer a denumerable set and we must completely re-orient our theoretical framework. In fact we need a continuous theory of population genetics to deal with the chromosomal continuum. . . . A "geneless" theory of population genetics will enable us to bring the observables of nature into a rigorous theory for the first time. (p. 71)

Not being an expert on genetics, I am not bold enough to discuss the essence of this assertion.

8

Searching for the difference between the animate and inanimate world, I am again ready to resort to the geometric vision of the World. Elements of the inanimate World, atoms or molecules, become elements of the animate World as soon as they start to enter a pattern open to the influence of the probabilistic space, morphophysiologically oriented. To be in a state of contact with this space means to have a possibility to respond to the changes in the system of probabilistically weighted evaluations (estimations). Here one can already discern the rudiments of consciousness, regarding the morphophysiological field as a semantic field of the animate World. The animate, in the process of its evolution, according to the Bayesian syllogism proves to be a carrier of the rudiments of consciousness. That is my answer to the question posed by H. Pattee (1968a): how do molecular-biological structures develop concrete biological functions? I propose the symbolic description of evolution which is complementary for a physical, atomic-molecular one.

9

And now a few words on Time. Time, as it is, cannot be measured; that was comprehended long ago by Plotinus (see Nalimov, 1982). An illusion that it can be measured emerges when there appears an observer with a clock. If we are able to imagine the World that has nothing in it, then it has no clock and, accordingly, no Time. The clock represents the aspect of the World manifestation that allows the observer to construct his own concept of Time. But the World is manifested through texts: it is with these words that this book began, and if we keep using this language, Time will merely be the grammar of texts of the World [I elaborated this idea in detail earlier (Nalimov, 1982)]. Thus, we have pairs of synonyms: Text—the Clock; Grammar of the Text—Time.

Our everyday concept of Time is constructed on the basis of observations over the variety of different but, roughly speaking, sufficiently well coordinated astronomical clocks.[25] But the observer watching the astronomical clock also has a clock of his own whose mechanism I explained previously (Nalimov, 1982), also on the basis of elementary geometric considerations. If we proceed from the concept of a multidimensional personality, then the multitude of personal Times should be assumed. Observing the living World, the researcher comes across a set of texts acting as a number of uncoordinated clocks: e.g., individuals, species, higher taxons, biocenosis, and the evolutionary process proper—each of its particular manifestations represents a specific clock. The same seems to be true of geological time.

My model of internal biological Time is directed at giving a geometrodynamic interpretation of a biological clock natural for our vision of the World. It turned out that in the living World there should be very many Times—they should be heterogeneous[26] and therefore uncoordinated. This statement is of a hypothetical or even maybe a natural-philosophical character: it can hardly be tested instrumentally.

Note that only part of biological clocks enter the field of vision of contemporary chronobiologists. If there exist biorhythms which are the

[25]Strictly speaking, different astronomical clocks set different times. I shall illuminate this statement by a few examples borrowed from the *Large Soviet Encyclopedia*. The system of astronomical registration of time based on the observations of the culmination of celestial bodies is not uniform. The difference between the mean and solar time (defined by the visible round-the-clock motion of the Sun) changes within the range between -14 minutes 22 seconds and $+16$ minutes 24 seconds. The uniformity of the system of time registration based on the Earth's rotation cannot satisfy some requirements even after certain corrections are introduced into it. The uniform system of time, *ephemeris time*, is controlled by the Moon's revolution around the Earth. The ephemeris time serves as the basis for compiling *Astronomical Annuals*. The definition of a second in physical units is based not on the Earth's rotation but on its revolution around the Sun called a *tropical* year. Now there exists a system of time registration independent of astronomical observations: the quartz clock controlled by an atomic generator (based on using the resonance frequency of an atom transition of cesium-133). All the systems of time registration are regularly compared with one another.

Atomic clocks, at least from a purely theoretical viewpoint, are not completely reliable. According to the concepts of general relativity theory, the observer on the Earth must discover that on the Sun the atomic clock is slower as compared with that on the Earth (the red shift corresponding to a higher gravitational potential). The solar observer, respectively, would notice that on the Earth the atomic clock is quicker (the blue shift). True, the relation characterizing the frequencies shift will only be 1.00000212, though it will be much greater for very dense stars (from Angel, 1980).

The transition from one system of time registration to another may greatly complicate the interpretation of the phenomena under observation. (For details see Chapter 2 in Grünbaum, 1963.)

[26]The concept of heterogeneous Time is not a prerogative of the living world. Modern physics (and cosmogony) include a problem whose discussion leads to a temptation to ascribe unusual properties to Time. Further evolution of physics will seem to involve a more profound comprehension of the nature of physical Time. However, I am not in a position to discuss this problem here.

object of study for chronobiologists, then there should exist biological pendulums. Record the formula setting the oscillation period for the mathematical pendulum.

$$T = 2\pi \sqrt{l/g}$$

where l is a length of the pendulum and g is the acceleration of a body in free fall. Assume that we measure the length of the pendulum by incorrect rulers. In this case the formula will naturally yield a set of different period values. Now let us take a correct ruler (correct within the system of our physical notions) and measure with its help the length of the imaginary biological pendulum localized in various sections of the biological space with amorphous metric.[27] We shall obtain a set of biological rhythms. The essential thing is that the formula of a pendulum acquires a double-faceted nature: in the right side of the formula, under the radical sign in the numerator is recorded the length of the biological pendulum measured by a common, physical ruler, and in the denominator is recorded the acceleration of a body in free fall set within the system of astronomical Time (pendulum motion and motion of the planets are regulated by a force of the same kind). The needed dimension of the right-hand part of the formula is preserved. Though everything said above is but a metaphor.

The proposed approach to describing biorhythms is of a much more abstract level and, therefore, is much more universal than the well-known alternative approach proceeding from the qualitative theory of differential equations setting concrete biological systems that function in a self-oscillatory regime. [A critical analysis of a relevant example, the "prey–predator" problem, may be found in Svirezhev and Logofet (1983).]

10

And now I wish at last to touch on another philosophical problem—that of a model *completeness*. We know how agonizing this problem is in quantum mechanics, the latter being not merely a theory, but also, in some sense, a paradigmatically fixed outlook. The discussion of the problem of completeness of quantum-mechanics formalism stemmed from the well-known argument between Einstein and Bohr. The discussion was not finished and, continued by others, is still going on (Bazhanov, 1983). It gave rise to new problems. One of them is the problem of physical reality. New concepts came into being. It became possible to ascribe a metatheoretical status to the theory: it could be *existentially incomplete* if its

[27]From the viewpoint of a naive observer it will look as if we measured the length of the pendulum in ordinary space bv differently incorrect rulers. Perhaps it is even possible to speak of the rulers' distribution according to their incorrectness and, therefore, of the distribution of biorhythms.

expressive and deductive means were insufficient to describe the phenomena and objects which are consistent with it.

The model I propose is existentially incomplete if only because it doesn't describe the evolution of texts in Time and therefore ignores such an important evolutionary factor as natural selection.

Note, however, that the impossibility for the model to be complete is implicitly built-in.

Indeed, in order to create a dynamic theory, it is necessary to come up to the next, hierarchically higher level of conceptualization allowing us to propose a model whose argument would be Time. However, from the model of the first hierarchical level developed above it follows that biological Time proper proves so variable that it cannot be related to the astronomical Time with respect to which changing systems may be described. We cannot resort here to the familiar formalism based on the notions of the derivatives, since there does not exist a homogeneous Time by which the derivatives could be taken. Being incomplete does not always signify the weakness of a theory. In our case the incompleteness of the theory is meaningful: it follows from the implicit potential impossibility for the theory to be complete.

As in physics, in our case the discussion of the problem of completeness is closely connected with the problem of existence. What is the criterion for the reality of the existence of biological time? It partakes of an illusory existence and remains difficult to grasp conceptually and therefore difficult to measure: measurement of biorhythms is not a measurement of all the variety of biological times. Perhaps the concept of a biological Time is nothing more than an attempt to find an image reflecting our vision of the irregularities of biological changeability. But it is possible to say the same of physical Time as well: this is also an image reflecting changeability but this time better arranged and regular enough. The introduction of various types of Time—physical, biological, and psychological[28]—seems to be nothing more than an attempt to describe the difference, not yet comprehended completely, between changeabilities typical for various manifestations of the World.

11

And now a few words of conclusion. The principal problem that arises when studying the living World may be formulated as a dialectics of opposition: *changeability* versus *stability*. The Bayesian syllogism is one possible model for describing this opposition. The syllogism includes the

[28]Earlier (Nalimov, 1982), I introduced the concept of physiological time whose rate of change is $V_t = dt/ds$ where s is a scale of Doing; its change of metric results in changing personal time. Physiological time proved to be a measure of an abstract space—that of Doing s. As was shown, such a model has a sufficiently meaningful explication.

concept of spontaneity of the creative principle,[29] of chance and necessity. The description of the living World is profoundly geometrical. The elementary constituent of the living World, an *individual*, may be called a bioexciton,[30] i.e., the excited state of geometry on which morphophysiological attributes are given. The bioexciton has an individuality limited by the quantitatively inexpressible requirement *to belong to a species*. Time becomes nothing more than a measure set by changeability, and this measure is amorphous.

[29]Note that the premises of my approach have much in common with the ideas of Koestler (1970). In his well-known book *The Ghost in the Machine*, written in a free and not strictly scientific manner, he speaks of the creative nature of biological evolution, comparing it with human creativity. Many of his assertions are similar to those of L. S. Berg, though Berg's book *Nomogenesis* is not mentioned.

[30]I have coined a new term analogous to a similar physical term, "exciton." (In physics *exciton* signifies a quasi-particle corresponding to the electronic excitation in the crystal of a dielectric, or semiconductor. The term derives from the Latin *excitātio*—excitation.)

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Chapter 4

Is Pangeometrism Legitimate?

Oh tell me, designer of desert,
Geometrician of quicksand,
Is that true that boundless lines
Are stronger than blowing wind?

O. Mandelshtam, 1933

For Kant space was an *a priori* form of external contemplation, the subjective condition for sense reaction. Hence followed the *possibility of geometry* as *a priori* synthetic knowledge. Time was, respectively, an *a priori* form of the inner contemplation of ourselves and our inner state (Kant, 1930).

> For time cannot be any determination of external phenomena. It has to do neither with shape nor position; on the contrary, it determines the relation of representations in our internal state. (Part I, Sect. II, §7, p. 30)

Today, as a result of Einstein's work, time has become geometric. There has emerged the tendency to speak not of space and time as separate entities, but of geometry in its abstract manifestation. Geometry proves to be the initial *a priori* synthetic knowledge that makes possible the contemplation of both external and internal worlds. Different geometries reveal different aspects of our World vision. Geometric images, despite their abstract nature, can easily be contemplated. Man is able to reflect by means of them the concrete nature of the World: we can speak of the spaces of movements, attributes, meanings, decisions, colors, and dreams. But those are actually not different spaces but different explications of often different geometries. Geometrization proves to be a means of conceptualization. The capacity for geometrization is an amazing fundamental faculty of the human mind. Resorting to measure as a manifestation of number is, as a matter of fact, the way toward geometrization. To be aware of something is to localize something in space in accordance with the requirements of a geometry, including here the dynamic geometry with changing properties. In general, localization is not merely a fixation, but a personification of some mental image by a geometric one.

Kant seems to have been the first philosopher who grasped the organizing role of Space and Time within the mind. But, of course, he was not able to foresee that man is *a priori* given not a Space in its everyday meaning, but the faculty of geometrization. And now we can say that, epistemologically, post-Kantian science not only provided man with individual concrete hypotheses (they come and go), but expanded the ability itself to contemplate, by opening the possibility for the free construction of new forms of contemplation of existence through a variety of geometries.

Now let us try to consider, at least schematically, geometric conceptualizations in various branches of knowledge.

Physics

As a result of Wheeler's generalizations, it became possible to assert that the evolution of physics may be regarded as the revelation of the World through its geometric comprehension. The book *Geometrodynamics* (Wheeler, 1962) includes as an appendix the article by Ch. Misner and J. Wheeler "Classical Physics as Geometry: Gravitation, Electromagnetism, Unquantized Charge, and Mass as Properties of Curved Empty Space." The authors consider in detail the possibility of a geometric description of electromagnetism. This is accompanied by resorting to space with a multiply connected topology allowing the existence of two or more topologically different paths connecting two points. In such a space electromagnetism turns out to be describable by means of topology and the theory of harmonic vector fields. It seems that one of the future trends of the evolution of physics will have a bearing on the localization in non-metric, topologically non-trivial spaces with a variable topology. However, at present Wheeler's geometrodynamics can hardly claim to be a complete success. Here it seems relevant to speak of the research program rather than a completed theory. I am not able to illuminate here the contemporary state of development of this program (see, for example, DeWitt, 1983).

Biology

In the present work I have attempted to consider one of the possible approaches to the geometric explication of evolutionism—primarily biological evolutionism—making use of the concept of a probabilistic space. This is far from being the first attempt at constructing a geometricized language fit for the symbolic description of the evolution of the living World. Earlier I mentioned the papers by Rashevsky and Rosen directed at founding abstract biology as a topological explication of the living World. Of great interest also is the approach of Waddington (1968a):

> If one wishes to formulate the phenotype in mathematical terms it is clear, then, that it is a function which involves the time variable. Moreover, the function must involve something more than merely the three dimensions of space, since we are interested in something more than the bare geometry of the organism. We shall need in fact one variable for each constituent (chemical or geometrical) of the system which is relevant to the question being considered. (p. 10)

He also introduces the concept of a multidimensional phase space corresponding to the entire multitude of the phenotype attributes (Waddington, 1968a):

> . . . within this space the phenotype will be represented by some kind of figure, which will begin at the point representing the constitution of the egg and will then be extended along the time dimension. Theoretically this figure might take the form of a bounded continuous sheet, for instance that of a triangle. If this were the case, one should find that, at some time after fertilization, the phenotype exhibited continuous variation in composition as one passed from one position within it to another. It is an empirical observation that this is normally not the case. In the organisms that we come across, we usually find a number of discrete and distinct organs—a liver clearly marked off both spatially and in composition from the kidney, and both of these from the heart, and so on. This means that the figure representing the phenotype has to branch out into a number of separate sub-configurations, each of which extends separately forward along the time dimension. (p. 10)

Further, he introduces the concept of a *chreod,* a canalized trajectory attracting the closest trajectories. Thus the possibility emerges to use a symbolic language for speaking about teleonomic self-regulation making the trajectories of epigenesis[1] stable with respect to the conditions trying to change them. In the language of abstract spaces of states, Waddington formulates the problems significant for the immediate future of evolution theory. One of them is as follows: Do there exist biological archetypes extended along the evolutionary scale of time? His answer is

[1]In Waddington's terms epigenetics is a branch of biology studying the cause-effect interactions between genes and products forming a phenotype.

> You don't just get a "horse archetype," a "Dipteran archetype," but you get a "horse family archetype," with inbuilt characteristics of directions in which evolutionary change can easily go. (p. 24)

The above statements by Waddington, though made by their author with great caution, again have a nomogenetic flavor.

The outstanding French topologist R. Thom emphasized the fact that Waddington's ideas of "structural stability," "chreods," and "epigenetic landscape" are in good correspondence with his own topological theory of stability of differentiable functions and mappings. He also proceeds from the idea that morphogenetic processes may be comprehended to a certain degree, leaving aside the properties of the substratum of forms and the nature of the operating forces. Thom formulates his approach in the most general way in the following lines (Thom, 1968):

> In all the natural processes, one has to isolate first the parts of the domain in which the process is structurally stable, "chreods" of the process, islands of determinism separated by areas where the process is undetermined or structurally unstable. By introducing dynamic models, we then try to dissect each chreod into "elementary chreods" connected with what I call "elementary catastrophies"; then we unite these elementary chreods into a global stable figure under the effect of singularity implicit for the dynamic system—"the organizing center." As to the arrangement of chreods that differ from one another, the problem seems more complicated since it cannot be determined in principle: among all possible configurations of different chreods, some are more stable than others; that will be those which are charged with greater "significance." This difficult problem is actually comparable to decoding a message in an unknown language. (p. 155)
>
> Contemporary biology turned natural selection into an exclusive principle, the *deus ex machina* of all biological explanations; its only mistake is that it treats an individual (or a species) as an irreducible functional entity. Actually, the stability of an individual or a species is based on the competition among "fields," among more elementary "archetypes" whose struggle produces a structurally stable geometric configuration that provides the regulation, homeostasis of metabolism and stability of reproduction. It is analyzing these subordinate, more deeply concealed structures that enables us to understand better the mechanisms determining morphogenesis of an individual or an evolution of a species. The "struggle" occurs not only among individuals and species but also, at each moment in every point of an individual organism. (p. 166)

Note also a later book by Thom (1975) where the philosophical foundations of his approach to the problem of morphogenesis are formulated like this:

> I think, however, that from an epistemological point of view an exclusively geometrical attack on the problem of morphogenesis is not only defensible, but perhaps even necessary. To declare that a living being is a global structure is merely to state an obvious fact and is not to adopt a vitalist philosophy: what is inadmissible and redolent of vitalist metaphysics is to explain local phenomena by the global structure. Therefore the biologist must, from the beginning, postulate the existence of a local determinism to account for all partial microphenomena within the living being, and then attempt to integrate all the local determinisms into a coherent, stable global structure. *From this point of view the fundamental problem of biology is a topological one, for topology is precisely the mathematical discipline dealing with the passage from the local to the global.*
>
> Pushing this thesis to its extreme, we might look upon all living phenomena as manifestation of a geometric object, the *life field* (champ vital), similar to gravitational or electromagnetic field; living beings would then be particles or structurally stable singularities of this field, and the phenomena of symbiosis, or predation, or parasitism, or sexuality, and so forth would be the interactions and couplings between these particles. The first task is, then, the geometrical description of this field, the determination of its formal properties and its laws of evolution, while the question of the ultimate nature of the field—whether it can be explained in terms of known fields or inert matter—is really a metaphysical one. (pp. 151–152)

Note that Thom's ideas, despite their abstract character, did not go unnoticed by biologists. According to *Science Citation Index*, his above-mentioned book (Thom, 1975) was cited in 1981 and 1982 69 and 65 times, respectively, including 7 and 10 times in biological journals. He also participated in the famous symposia on theoretical biology organized by the International Society of Biological Sciences whose proceedings were edited by Waddington.

Historically, it seems relevant to mention here other, less abstract attempts at biological explication of the field conceptions. In the USSR the well-known embryologist A. G. Gurvich started to develop the idea of a biological field between 1912 and 1922. In his later book (Gurvich, 1944) he asserted that the source of the biological field lay in the biochemical processes occurring in the cell nuclei. He postulated the presence of a direct (not mediated by the environment) intercellular interaction, though this was not supported by direct experiments (Belousov and Chernavsky, 1982). It is important to note that Gurvich refused to speak about the physical nature of the morphogenetic field. Gurvich's ideas were further elaborated by L. V. Belousov (1971). Analyzing the process of formation of an embryo, he again came to the idea of a morphogenetic field which formally satisfies a number of data, though the physical-chemical nature of the field remains vague. For us it is essential that Belousov (1971) feels the necessity of resorting to the idea of a spatial distribution of sensitivity in embryogenesis:

> Indeed, since genes by themselves may be referred only to the activation factors, they may bring about local effects only in case of the uneven spatial distribution of sensitivity of the embryo elements to the gene action, produced earlier by the complicating factors or external heterogeneity. (p. 158)

I believe that the revelation of the biological meaning of the morphogenetic field is primarily hampered by the biological paradigm requiring that this concept be filled with too concrete, physically tangible content. The concept of a field has been borrowed from physics, and it should be treated with the nonrigidity allowed by abstractly oriented physical thought. For example, what can physicists say concerning the substantiality of the gravitational field?

However, Belousov and Chernavsky (1982) note that the interest of biologists in the problem of morphogenetic fields has recently revived: see, for example, the paper by French et al. (1976) proposing a formal model for regulation of a spatial pattern in epimorphic fields. In accordance with the model the cell uses a two-dimensional polar system of coordinates for assessing its position within the developing organs.

Note also the recent article by Lewin (1984) that considers briefly the widely known fundamental research by Sydney Brenner devoted to the detailed study of development of a tiny nematode whose body has a total of 959 cells, 302 of which constitute its nervous system. The article reads as follows:

> What has been achieved so far—the complete description of the anatomy and cell lineage, the genetics and an entry into the molecular biology and biochemistry—is an excellent and revealing beginning. But an understanding of how the information encoded in the genes relates to the means by which cells assemble themselves into an organism—"the mapping of genetic space onto organismic space" still remains elusive. (p. 1327)

Here again, we see that the geometric problem remains unsolved: there is no language that would set a *formation* on the organismic space. Perhaps the language of probabilistic notions will serve as such, since it allows, by means of discrete values, distribution function parameters, a change in the weights set on the field of morphophysiological attributes. And if this is so,

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then this is exactly the illogical development that was emphasized by Lewin in the title of his article.

I would also like to draw the reader's attention to research in cryobiology. Morowitz (1967) found that a large number of biological systems held at temperatures near to absolute zero on rewarming continue their biological activity unimpaired. Generalizing these results, it becomes possible to assert that biological information is retained in a spatial structure:

> At the molecular level information can be stored in two ways, either in molecular structure essentially in the specification of covalent or secondary bonds or in dynamic processes such as the flow of intermediates or the conduction of electrical pulses. At absolute zero all processes cease and the system is a pure structure. This structure retains all the relevant biological information (warming is a disordering process in the thermodynamic sense). (p. 46)

Linguistics and Textology

In attempting to explain why people do understand one another even if their languages lack words with monatomic meanings, I naturally resorted to the conception of semantic fields probabilistically interpreted in linguistics (Nalimov, 1981a). There are, of course, other ways of geometrizing linguistic reality. I again mention Thom (1970), who thought it possible, on the basis of topological concepts, to give a spatial interpretation for practically any linguistic expressions. Thom (1970) has compiled a list of singularities, elementary catastrophies,[2] and ascribed to them linguistic interpretations that form morphologies—archetypes through which semantics and syntax of the simplest French phrases (those describing space–time processes and states of objects) are revealed.

Of interest is a rather unexpected speculation by the philologist V. N. Toporov (1983) asserting that text is space, and space is text. The following excerpt from his work has much in common with my ideas.

> Space is prepared to admit objects, *it is receptive and yields itself to them,* ceding them its *shape* and offering in return its *order,* its rules of constructing objects in space. The absolute indiscernibility ("muteness," "blindness") of space expands its content via objects. Due to this the

[2]In his applied research Thom always proceeds from his theory of catastrophies which became very popular in the West during the 1970s. Catastrophies are spasmodic changes emerging as a sudden response to the smooth change of external conditions. This is a dynamic vision of the World revealed through geometric images. The source of the theory of catastrophies is the *bifurcation* theory that describes qualitative reconstruction of objects when their parameters are changed. The popular exposition of the theory of catastrophies is given by Arnold (1983), and a more detailed one is given by Gilmore (1981).

> property of space to be disintegrated is realized, it acquires "voice" and "image," it becomes audible and visible, i.e., meaningful (in the spirit of ideas of Proclus's "fundamental principles of theology"). The *space on this* level is a symbol, a meaning. Moreover, objects within the space illuminate a specific *paradigm* represented by these objects, and their own order, a *syntagma*, i.e., a *text*. This "text of the space" has a *meaning* perceptible both from above (something like the Whole in Proclus's teaching, *by that for which nothing is too shallow*) and from below, through a series of intermediate emanations when there emerges a subject to comprehend this "text of the space" belonging already to a standard type. In this sense it is possible to speak of space as a *potential* text, its receptacle (such that it is related to the text by its filling). At the same time *realized* (actualized through objects) space should be understood in the framework of this conception as a text itself. (pp. 279–280)

Here texts are viewed as a result of comprehension by the subject of the mute meanings of the space. This almost literally coincides with what I have said about evolutionism. In my speculations, the subject comprehending the mute meanings of the space is represented by Nature.

The words by Toporov have much in common with the words on time and space said by an original Russian writer of Korean origin, A. Kim (1984):

> Time is said to exist because an event takes place and then it does not occur any more. Some events occur in the space, say, [when] someone's life is going on, but it is only space that changes, and this is called time, Lilianna. Change of space is life, not the sad loss of time, as we think. We do not lose anything. Space always remains where it was but it changes thanks to our lives. And also thanks to the movements of cloud, wind, birds, animals, brooks and rock falling into the sea. . . . You are but a part of the ever-changing world space, accidentally named Lilianna. (pp. 187–188)

It seems odd: such concepts arise spontaneously in the mind of an author free of any theoretical constructions.

Consciousness

Earlier (Nalimov, 1982), I showed that processes occurring on the deep levels of consciousness should be regarded using probabilistically weighted semantic fields. This opens up a possibility of applying Bayesian logic, which is more flexible than Aristotelian logic, though, of course, less precise. I succeeded in constructing an image of personality within probabilistic spaces, including such of its aspects as *ego, meta-Ego,* *multidimensionality, hyper-Ego.* Historically, it is necessary to indicate that the first attempt at a geometric representation of a personality was made by Kurt Lewin (1936). He tried to solve this problem by resorting only to elementary topological notions. Rejecting the classification method of personality representation, then prevailing in psychology, Lewin tried to construct a structural image of a personality. Of interest is his stratigraphics of a personality under various conditions: geometry of a calm state and those of stress and great tension.

Note also the topological models of consciousness by Zeeman (1965). Starting with algebraic topology, he attempted to construct a model (though fairly schematic) connecting neurophysiological brain activity and such manifestations of consciousness as memory, learning, color vision, and auditory perception. In another paper, Zeeman and Buneman (1968) resorted to the topologically fuzzy, *tolerant* spaces and gave a geometric interpretation to the emergence of indefiniteness in memory, thinking, and comprehension of meaning.

In modern psychology a new branch has recently appeared, now of an appendix nature, known as *transpersonal psychology*[3]; it represents an attempt to study human consciousness beyond the boundaries of its discrete capsulization. In my terms, personality within this branch may be interpreted as a manifestation of the semantic field. Through this field consciousness interacts with itself and with the integrity of the world.

In connection with the problem of artificial intelligence, interest in the concept of space metrics in mathematical thinking became more acute. I quote the mathematician Hofstadter (1980) on this point:

> Every mathematician has the sense that there is a kind of metric between ideas in mathematics—that all of mathematics is a network of results between which there are enormously many connections. In that network some ideas are very closely linked; others require more elaborate pathways to be joined. Sometimes two theorems in mathematics are close because one can be proven easily, given the other. Other times two ideas are close because they are analogous, or even isomorphic. These are two different senses of the word "close" in the domain of mathematics. There are probably a number of others. Whether there is an objectivity or a universality to our sense of mathematical closeness, or whether it is largely an accident of historical development is hard to say. Some theorems of different branches of mathematics appear to us hard to link, and we might say that they are unrelated—but something might turn up later which forces us to change our minds. If we could instill our highly developed sense of mathematical closeness—a "mathematician's mental

[3]*The Journal of Transpersonal Psychology* has been published since 1969. The bibliography of this branch of knowledge comprises about 800 items in English (Murphy and Donovan, 1983).

> metric," so to speak—into a program, we could perhaps produce a primitive "artificial mathematician." (p. 614)

In other words, artificial intelligence could be moved closer to mathematical thinking if we succeeded in comprehending the metric properties of the human space of thinking.

And while earlier, following Kant, I asserted that space was a form of contemplation of the external World, now proceeding from the above, I am ready to go even further and assert that consciousness itself is geometrically structured: *man is geometric existentially*. To my mind, this conclusion is of major significance for philosophy.

Wishing to support the argumentation for the above assertion, I will emphasize here the geometric conditioning of visual perception. Our visual perception is not a mechanical transference of the external World into our consciousness, but its complex reproduction satisfying definite geometries. This subject is thoroughly illuminated by Petukhov (1981). As long ago as in the 1940s, Lunenburg (1947, 1948, 1950) formulated an experimentally grounded assumption that the space of human visual perception is characterized by Lobachevsky's geometry. This assumption later received a broad and favorable recognition. Lunenburg's concept was especially thoroughly tested by Kienle (1964). The geometrical approach was applied to great advantage in the theory of color perception. The famous physicist Schrödinger, who also studied the theory of vision, based his work on the ideas of projective geometry while investigating physiological laws of color mixtures (Schrödinger, 1920). H. von Shelling (1955, 1956a, 1956b, 1960, 1964) introduced a non-Euclidean metric to describe color perception and constructed perception relativity theory analogous to the concept of the space–time manifold in the special relativity theory. Reznikoff (1974) resorted to differential geometry to study color perception. Even from such a cursory review, it follows that visual perception of the World is its representation through the texts of our consciousness constructed on non-trivial geometrics.

Paraphrasing slightly the idea of Petukhov (1981), we may say that, when in our consciousness texts are constructed through which we perceive the World, what is taking place there has very much in common with what happens in morphogenesis. We are ready to discover in the depths of consciousness the same geometric images that occur in morphogenesis. Hence, it becomes clear why the mechanical pressure of the eyeball produces phosphenes—simple geometric figures in the field of vision. I considered this phenomenon earlier (Nalimov, 1982), stressing parallels with children's drawings and folk ornamentations. It is well known that when we turn to the World of our unconscious, first of all we come across geometric figures that acquire the status of symbol-archetypes (see Nalimov, 1982, Chapter 12). Figures 8 and 9 present post-meditational pictures by the professional painter A. Dyachkov (the pictures were painted on the basis of color sketches made directly after meditation). These pictures can be compared with *jantras*[4]—complex tantric symbolic constructions built of abstract geometric symbols. The meaning and purpose of jantras are versatile. On the one hand, they carry some metaphoric charge symbolizing cosmic unity; on the other hand, they are used in rites and meditations to make possible the journey inside one's Self, to merge one's personality and cosmic element. Looking through a book (Madhu Khanna, 1979) devoted to jantras, I noticed, not without a slight amazement, that in the tantric constructions the basic elementary symbol is most often the triangle which occurs so often in the pictures of Dyachkov. One of the jantras is shown in Fig. 10. Perhaps this is connected with the archaic traits of consciousness, with those of its manifestations that go back in the distant past not only of anthropogenesis, but also of phylogenesis since one of the structural constituents of our brain affecting consciousness has roots in the remote phylogenetic past. Perhaps it is relevant to remind the reader of what was said earlier in this book on the role played by the number *three* in the living World. The triangle is the simplest geometric manifestation of this number. Now we can give a purely *geometric interpretation of the symbol of trinity*, the triunity.[5] A triangle (in mathematics simplex, the simplest figure on a plane) is peculiar for the fact that the three points forming its vertices can be regarded on the one hand as independent elements; on the other hand, they *form the simplest geometric figure*. Perhaps hence comes the idea of trinity. In ancient times man, or, rather, his forefather who first understood it, made a striking discovery and began to think spatially. It is this discovery, crucial for human evolution, that was imprinted in the metaphor of trinity.

I am now looking through an article by Dyer and Gould (1983) on honeybee navigation. I learn from it that bees are born geometricians. One of the explanations of their ability to navigate is as follows: ". . . the bees perform some complicated assessment in their brains that is tantamount to spherical trigonometry" (p. 593).

Strikingly geometric is the behavior of euphausic shrimp (Zelikman, 1982). They live in the circum-antarctic belt, usually in schools forming definite geometric figures. The density of population in such schools is immense: 10,000 individuals (each about 3 to 6 centimeters) in one cubic

[4]Jantra is a Tantric symbol of cosmic unity. Actually it is a complicated abstract geometric composition. It is used as a tool for rites and meditations. Being a diagram of power, it helps a person in the spiritual journey directed to the initial center, the unity of personality and cosmos. Jantras vary in accordance with their concrete application.

[5]The idea of the trinity is the principal dogma of Christianity. The concept of the nature of Gods is rooted in the most ancient past. Jung (1984) seems to have said everything about it that can be said. For him the Trinity is an archetype whose dominating power not only fosters spiritual development but may, on occasion, actually enforce it (p. 89).

Fig. 8. *Fiord*—a post-meditational picture by the painter A. Dyachkov (the original is in color).

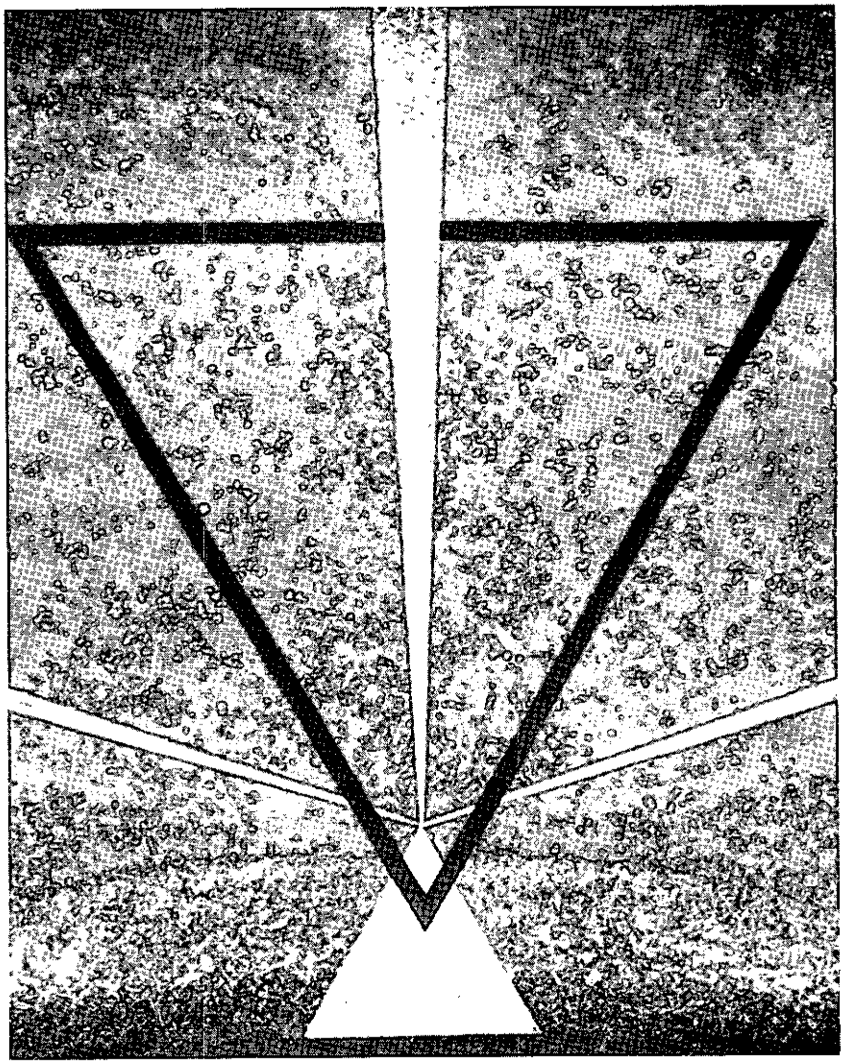

Fig. 9. *Triangles*—a post-meditational picture by the painter A. Dyachkov (the original is in color).

meter of water. From on board ship such a school may appear as a stretched ellipsoid-like figure or as a ribbon-like dumbbell-shaped surface. If a sailing ship breaks such a formation, it is restored immediately. When a predator approaches it, the school scatters rapidly, leaving behind a cloud of molt sheaths, and then gathers together again. I could, perhaps, cite a lot of other examples of geometric arrangement of animal movements, e.g., the flight of cranes, etc. Does it not follow from these facts that the ability of

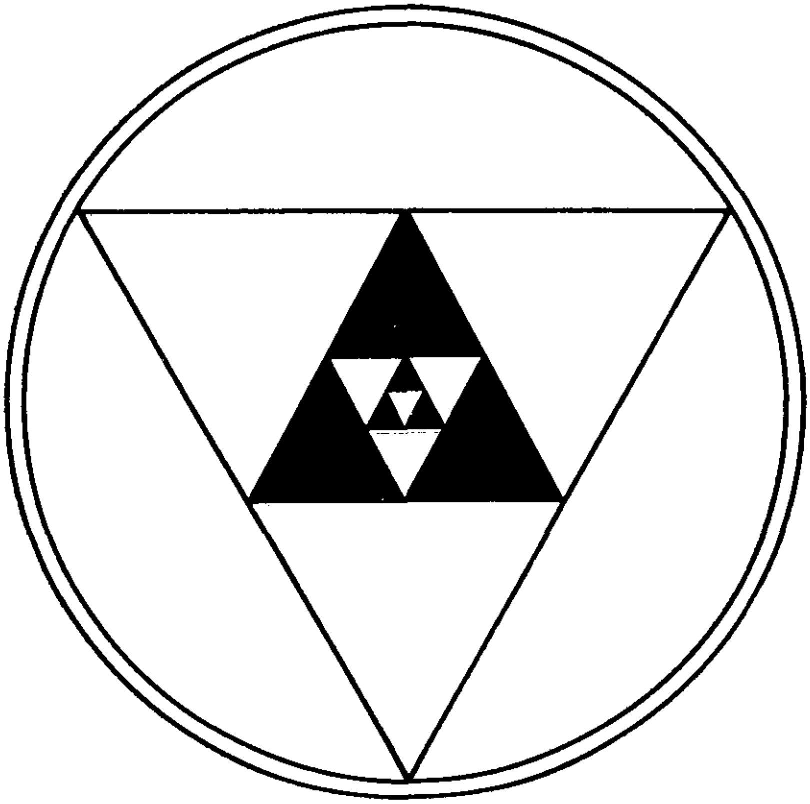

Fig. 10. Smar-hara Jantra (detail), the "remover of desire." The circle is the latent Kundalini, which when aroused can penetrate beyond the successive planes of inwardness illustrated by the five male and female triangles which correspond to the five psychic sheaths that envelop the innermost self (Madhu Khanna, 1979, p. 143).

man to prefer some geometric figures to others is built into the relic forms of consciousness whose roots go back to the phylogenetic past?

The Voice from the Distant Past (Anaxagoras)

Now let us turn to the sources of contemporary thought.

The concept of space as the fundamental principle of the World is primordial. It is preserved somewhere in the storeroom of consciousness. It had emerged earlier than geometry. The image of space is one of the archetypes of our consciousness. This image in its geometric form has become a key to the World of new ideas through which the vision of the

World is revealed in contemporary science. However, its roots go back into the remotest past. For example, here is what we read in the Vedas[6] (Upanishads, 1959):

> 9.1. "WHAT IS THE SUPPORT of this world?" asked Śilaka. "The ākāśa," said Pravahana. "For all these beings are created from the ākāśa and return to the ākāśa. The ākāśa is greater than these; therefore the ākāśa is the supreme support." (p. 139)

The word *ākāśa* can be rendered as *space.* At least this is what Russian Indologists do when translating Chhāndogya Upanishad.

I chose as an epigraph to Chapter 18 of my earlier book (Nalimov, 1982) lines from the Bhagavadgita revealing a strikingly deep understanding of the all-embracing role played by the field.

But perhaps the most vivid concept of the geometric (in modern terms) fundamental principle of the World belongs to Anaxagoras, one of the most profound thinkers of early Greek philosophy.[7] His constructions represent an attempt to view the World through abstract images. We have here products of direct speculations and in no way results of perfect logical reasoning. In any case, Theodorsson (1982) begins his book about Anaxagoras with the following words: "Anaxagoras is a fascinating, not to say mysterious, personage in Pre-Socratic philosophy" (p. 7). His ideas have reached us only in the form of 17 fragments occupying 3.5 pages in the book by Theodorsson. But these fragments became subject to commentary from the days of Plato and the comments are still going on. Their volume is several orders more than the fragments themselves.

Any attempt to translate the mysterious words of Anaxagoras into a modern language is extremely difficult. I would rather speak about referring them to some sufficiently abstractly formulated modern systems of views. This seems to be the way of understanding texts whose meaning was lost long ago.

Theodorsson, making a critical analysis of the most interesting comments on Anaxagoras's *theory of matter,* formulates its basic principles in the following succinct words:

1. No Becoming.
2. Plurality.

[6]Misner and Wheeler (1957) in "Classical Physics as Geometry" also draw attention to the fact that in some canticles of the Vedas one may come across the idea that nature borrows its structure from space. They refer to Taittiriya Upanishad.

[7]Anaxagoras's biography is vague: he was born about 500 B.C. and died in 428 B.C. At the age of 20 he arrived at Athens and remained there for 30 years till he was ostracized after being accused of atheism. Noteworthy is the following assertion according to which, in ancient Greece, the views of Anaxagoras were regarded as belonging to the distant past (*Antichnye filosofy,* 1955): *Diogenes Laertius.* According to *Democritus,* "his views are not his own, but borrowed from old men" (p. 64).

3. Everything Together or Unity.
4. Infinite Divisibility.
5. Infinity.
6. Predominance. (p. 66)

He remarks that all those principles except the last one may be deduced by proceeding from the analysis of the initial phrase of the first fragment: "All things were together, infinite both in number and in smallness, for even the small was infinite" (p. 97). All the above principles are easily correlated with our structures:

1. The process of evolution does not presuppose any formation, i.e., production of something new, but is a new manifestation of what exists eternally.
2. Any manifestation is based on ascribing weights to the initial plurality.
3. Everything together, since all entities existing in the animate world are nothing more than different forms of manifestation of the same things.
4. Infinite chance for manifestation.
5. What is manifested is infinite (moreover continual).
6. The essence of the manifested is determined by predominance, i.e., by the selectivity of distribution function $p(\mu)$ set on the scale μ.

It is very difficult to interpret Anaxagoras's ideas on *seeds* ($\sigma\pi\epsilon\rho\mu\alpha\tau\alpha$), certain discrete units. How can this concept be related to the following assertion by Anaxagoras:

> And since the features of the great and the small are equal in number, for this reason, too. All (things) will be in everything. Nor is it possible to exist apart, but all (things) share a feature of everything. Since it is not possible that there should exist a smallest, it will not be possible for anything to be put apart nor to come by itself, but as it was originally, so even now all (things) must be together. And in all (things) there are many and they are equal in number in the greater as well as the smaller of those (things) that are separated off. (p. 99)

Within our system of notions separate seed may be correlated with what is given by the distribution functions $p_1(\mu)$, $p_2(\mu)$. . . . They are all given on the same field of attributes μ; consequently, they share the same features. They are all equal in number, since their individualities are given by a measure always normalized to unity.

Further, according to Anaxagoras, all the Seeds are formed from Opposites. In our model, too, the scale μ also possesses opposite attributes, but the formation of individualities (unpacking of what is given on the scale) takes place not by dissecting it into the opposites but by attaching to different parts of the scale different weights. The general tendency of the above system of concepts may be regarded as a possible interpretation of Anaxagoras's teaching on the existence of opposites, when all (things) are in everything.

In our interpretation, the term *Seeds* acquires a biological meaning. The same tendency is observed, according to Theodorsson (1982), in some other authors. Hence comes the possibility of regarding the Seeds as the initial forms of the evolutionary process: originally, qualitatively different forms $p_{01}(\mu)$, $p_{02}(\mu)$ . . . must have existed that could later evolve.

It is noteworthy that Anaxagoras speaks not only of coming to be, but also of passing away:

> B.17. The Hellenes do not have a correct opinion about coming to be and passing away; for nothing comes into being nor does it pass away, but it is mixed and distinguished out of existing things. Thus they will be right to call coming to be mixing, and passing away distinguishing. (p. 103)

In our terms everything that comes into being is created in the process of unpacking of the initial semantic continuum by attaching to it measure binding its different sections, and when the measure changes, everything passes away.

And while we connect the creative process with the spontaneous emergence of the new information $p(y|\mu)$, Anaxagoras connects it with mind.

> B.12. Other things share a feature of everything, but mind is infinite and self-ruled and is mixed with nothing, but is alone, itself by itself. . . . And those (things) that are mixed together and separated off and distinguished, all these mind got knowledge off. And all (things) which were to be and all those that were but are not now, and all that are now and all that shall be, mind arranged them all. . . . (p. 101)

I would like to note in conclusion that my interpretation of Anaxagoras has much in common with that of Theodorsson (1982):

> The things of the world are not autonomous; there are no intervals between them; everything was and is a continuum (B6). . . . Discussion, or abscission, cannot be in Anaxagoras' universe. (p. 86)

We see that very long ago, at the beginning of culture, the attempt was made to reveal the geometric structure of the universe. Everything said above testifies to numerous attempts to revive a pangeometric vision of the World. The most outstanding personage here seems to have been Einstein. A pangeometric archetype also affected the poet Osip Mandelshtam whose verse has been used above as an epigraph.

* * *

I have attempted here to review the papers that may be placed, to my mind, into the stream of pangeometric tendencies. This review is very brief and incomplete and, perhaps, not sufficiently profound. I only mentioned such an important geometric problem as symmetry and asymmetry; that problem would require an independent study. The papers embraced by my review are also characterized by various degrees of submerging the object of study in geometric concepts. But the major tendency is quite distinct: to see the World through its geometric principle. For more than twenty centuries European thought has been developing as an opposition: idea versus matter. It was rigid and non-dialectical. Now we are witnessing a new tendency aimed at linking those two opposing elements through geometry. Geometry represents something extra-substantial, extra-objective. It is Nothing. But it is not the Nothing of the ancient Oriental philosophy. Here *Nothing* becomes *attributive:* we may characterize geometry by various attributes and properties. Number and its generalized representation, measure, are among the properties by means of which geometry becomes attributive.

And still: Is pangeometrism legitimate?

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Chapter 5

How Is Theoretical Biology Possible in the Geometric Vision of the World?

1

Theoretical biology does not exist so far. There is no such chair in Moscow University. There is no such course of lectures. This is not to say that biology never resorts to theory. Theoretical structures seem to penetrate all its branches. But these structures cannot be united semantically: taken together, they do not form what can be called *theoretical biology*. The far-reaching mathematization does not seem to have helped much either: about fifty monographs to the point have been published in the famous series "Lecture Notes in Biomathematics" (Springer Verlag, Berlin), but they have not formed a foundation for theoretical biology.

The famous four-volume work *Towards a Theoretical Biology* edited by Waddington (1968, 1969, 1970, 1972) also left the problem open. In the epilogue, Waddington remarks that it had to be entitled more modestly, namely, *theory of general biology*. Indeed, we can find there not the assertions but rather problem formulations of a general biological character. The abstract, i.e., mathematical, image of the animate world still remains to be found. But this is exactly what matters. How can it be discovered? What will it look like? Those are the questions that, to my mind, are now ripe for discussion.

Perhaps the key problem of theoretical biology could be formulated as a dialectics of opposition: *changeability versus stability*. Why does everything in the living World exist in such an extreme variety? Why is everything exposed to this unpredictable changeability? Why is changeability locked with stability so that we, people, are prone to perceive this stability as something harmonious? In what language is it possible to describe the variety and its changeability so as not to lose the object of description? What properties should biological Time and Space possess to be the site in which the biological script is played? How does the stability and changeability of the physical world principally differ from that of the animate world?

The answer to the last question could, perhaps, be as follows: stability of the physical World is determined by the rigidity of numerical constants, whereas that of the living World is determined by numerical fuzziness. But this paradoxical answer has to be fully comprehended.

Ecological literature is full of theoretical speculations devoted to the problem of "changeability versus stability.[1] But they all are struck by the disease of the incomplete inclusion of the biological problematics proper; that was discussed in much detail by Simberloff (1980), Vinberg (1981), Brown (1981), MacIntosh (1980), and Rigler (1982). These models are mechanistic; biological script is submerged into physical space and time, and sometimes it is reduced to anthropomorphic conceptions. We cannot seriously hope that ecological problems will be fully locked to the energetics of resources relying on the aphorism "Eat or be eaten."

MacIntosh (1980) said: "The difficulties of developing a body of theory in biology or ecology are paralleled by difficulties in developing a philosophy of biology" (p. 244).

Indeed, if we wish to break from the fettering influence of positivism, it is necessary to introduce the philosophical-sounding idea of non-trivial spontaneity which will immediately lead the consideration of the above-formulated problems out of the sphere of reductionism. If metaphysical concepts do not frighten us, it will be better to introduce the idea of "biological pre-consciousness" and thus to overcome the reduction to mechanistic concepts. In this respect it is of interest to note the article by Efron (1977) emphasizing that it is as a result of reductionism that ". . .-many biologists seem to have lost contact with reality."

It may seem strange, but the philosophical renovation may come via mathematics. Mathematics is versatile in its applications. It is, perhaps, too schematic, but I shall consider here three major (in my opinion) trends in the mathematization of knowledge.

The first one is an *empirico-mathematical* trend. The mathematician-modeler constructs a model proceeding, on the one hand, from the empirical data he is provided with and, on the other hand, from ambiguous explanations of the researcher. Sometimes the model is also chosen by the researcher, and the mathematician has only to provide consultation. Mathematics acts here simply as a new language allowing us to represent experimental data in a compact and comprehensible way. Recall that Ronald Fisher, one of the founders of mathematical statistics, believed that

[1]In their very interesting book, Svirezhev and Logofet (1983) give the following formalized ecological definition of stability: ". . . a community is *stable*, if the system of differential (or difference, or differential-difference, etc.) equations, which is a model of this community, has a stable non-trivial positive solution" (pp. 13–14). However, here the question arises immediately: can a variety of biological changeability be expressed by a system of differential equations? In any case, the authors of the above book finish it with the following words: "We are still too much restricted by the burden of ideas and concepts from classical stability theory, and therefore any new ideas, concepts, methods may be only welcomed" (p. 316).

its task was the reduction of data. Compact representation of data makes them easily grasped, and as a result, the model by means of which the reduction is achieved may acquire heuristic power. However, in such an approach, mathematics does not introduce any general new ideas; it remains a tool revealing what is implicit in the experimental data. This is not a synthetic way, but an analytical one. It is hardly possible to believe that such use of mathematics may lead to the construction of theoretical biology.

The second trend is *paramathematical.* A mathematician, or even more often an engineer, elaborates a new discipline brought about by mathematics but situated outside it (but very close). Such a discipline is oriented toward solving a family of problems close in their formulation but related to domains whose objects are very distant from one another. Resorting to experiments is here generally superficial: it is interpreted within the framework of a general model elaborated beforehand but allowing us to make a meticulous analysis of the data that takes place in the first trend. Below are given a few examples of the second trend in the mathematization of knowledge. The theory of *fuzzy sets,* so popular now, may serve as such; it was developed by the American scientist Zadeh.[2] Other illustrations are the *general theory of systems* (or *systemotechnique*) and the *theory of catastrophies* by René Thom mentioned above (it is based on the mathematical constructions proper: *singularity theory* and *theory of bifurcations*); the theory of stability of *dynamic systems* can also be referred to here. Such structures may sometimes be refined, though, as a rule, they lack profound mathematical meaning (a nice exception was *information theory,* which, having emerged from the solution of a concrete engineering problem, soon acquired the status of a mathematical discipline though it simultaneously became separated from the applied problems). With respect to the world of empirical observations, mathematical models act rather like metaphors, often making the comprehension of the phenomena observed easier. For example, in contrast to the classical theory of stability, the theory of catastrophies allows for the existence of several structurally stable *attractors* in the phase space acting on the transitional neighboring stable regimes. Thus, the possibility of simulating morphogenesis is opened up. However, the weak point of the theory of catastrophies is its superfluous generality: it claims to be able to investigate, as it seems, all possible spasmodic transitions. It may be applied, with equal success, not only to biology and linguistics, but also to optics, to simulation of mental diseases, ship stability, revolts in prisons, etc. (Arnold, 1983). Such an expanded approach can hardly acquire the specificity necessary to become the basis for the evolution of a theory of the animate World. At the same time we are quite aware of the fact that

[2]In my earlier book (Nalimov, 1981b) a chapter is devoted to the criticism of Zadeh's concepts.

theoretical biology cannot emerge from the aggregation of specifically oriented mathematical models of which biophysics is full. Where is this hardly discernible demarcation line between generality and specificity, and should it be looked for or is it more reasonable to take the road of another problem solution? Note another phenomenon related not so much to science as to the sociological aspects of its evolution. Paramathematical trends of thought strikingly readily attract the publicity that is alien to serious science. This is what happened to the theory of catastrophies. This is also what happened to information theory at the moment of its formation. Cybernetics, an undoubtedly paramathematical discipline, began its career in much the same way.

The third direction could perhaps be called *metaphoric-mathematical* proper, or even *mytho-mathematical.* In this case the researcher does not invent new mathematical structures but takes the already existing one and ascribes to it a new, unexpected explication within the system of presentation of the empirical World, introducing for this purpose only one or several axioms of a related kind. Mathematical structure starts to act like a myth that the researcher interprets anew, as was done by the ancient thinkers with myths of their epoch. In this way the object area is enriched by the new ideas coming from mathematics and giving birth to a new vision of the World. A good example of this attitude is the *general relativity theory:* Einstein made the concept of gravitation[3] geometric by exploiting already-existing structures: Riemannian geometry and tensor analysis.

The following lines written by Manin (1979) have much in common with my ideas of the third direction of the mathematization of knowledge.

> The mad idea which will form a foundation of the future fundamental physical theory, will be the realization of the fact that a physical meaning has a mathematical image which has not earlier been connected with the reality. From this point of view the problem of a mad idea is that of choice, not of production. . . .
>
> A reader may need an effort of will to see in mathematics the teacher of imaginative thinking. (p. 4)
>
> A good physicist uses formalism as a poet uses natural language. Negligence of rigorous prohibitions is justified by the ultimate appeal to the physical truth, which a mathematician cannot do. The choice of a Lagrangian in the united Salam-Weinberg theory of weak electromagnetic interactions, introduction of Higgs fields there, subtracting vacuum averages and other "witchcraft" leading to the forecast of neutral currents leaves a mathematician dumb puzzled. (p. 8)
>
> The true change of theories is not merely a change of equations, but a change of mathematical structures. (p. 32)

[3]He assumed the possibility of existence of a physical space with a variable curvature. That was so unusual that even such a thinker as Whitehead objected to this assumption (see, e.g., Nagel, 1961).

It should be noted that the third way of mathematization of knowledge remains so far the prerogative of physics. And as a result, mathematics has become an inseparable, organic part of physical knowledge.[4] In the Preface to an earlier book (Nalimov, 1982), I made the following assertion: "[physics] taught us to explain *the incomprehensible comprehensibly by the much more incomprehensible.*" The other branches of knowledge act differently: they try to explain the incomprehensible through the comprehensible, i.e., through the fundamental conceptions of the world order that man had developed in the process of anthropogenesis, when the horizons of reality were not yet expanded and the World could be revealed through myths that now seem to us utterly naive.

Is the third way of mathematization possible in other branches of knowledge, in biology, in particular? Some attempts in this direction seem to have been made. The above-mentioned approach by Rashevsky is one of them, though its explanatory power proved insufficient for most biologists to perceive it. My model is also an attempt to follow the third way of mathematization. By force of its abstract character, it turned out to be so broad as to embrace evolutionism in all its expansions. But will its explanatory power be sufficient for the biologists to get interested in it? Can a model without a prognostic power have the right to exist?

2

Now let us try to consider a problem of constructing theoretical biology in another aspect. Any theory starts with the formulation of meaningful problems. In theoretical biology, at least at the initial stage of its development, they will be, I believe, of a biophysical nature. They will emerge from the comparison and opposition of the fundamental concepts of physics and biology. It is such an opposition that may serve as a starting point for the revelation of biological theory proper. And this is a very convenient starting point, since physics is a profoundly conceptualized science. Besides, that is not the notorious reductionism: reducing biology to physics. The initial position is different: the conception of the World's holisticity. However, the idea of holisticity should not conceal the individual manifestations.

3

If theoretical biology is constructed, its language should differ from that of physics since the variety of manifestations of the living world is essentially different from the variety of phenomena physics deals with.

[4]Note also a very essential circumstance: it is in physics that mathematical images produce models that are easily put into correspondence with the results of a physical experiment. They can be tested quantitatively (falsified, in terms of Popper). Moreover, in physics forecasting of new phenomena is also possible, and that makes the model almost invulnerable to criticism. In biology, a model cannot acquire a prognostic power because the animate World lacks the basic landmarks—fundamental concepts.

Attempts at constructing theoretical biology represent primarily the search for a new language adequate for the striking variety of the animate world.

4

The unity of physical knowledge is determined by the fact that it is based on the conception of space–time fundamental for physical theory. Physics did not grasp the role of space from the start: the understanding that the World structure can be revealed through the image of space in its mathematical interpretation came into existence only gradually. We find the sources of space constructions in the concept of electromagnetic field introduced by Faraday and Maxwell, though the first sprouts can be found even earlier in the Copernican revolution completed by Newton's mechanics. The essentially new comprehension of space–time was revealed through relativity theory, though Einstein did not succeed in creating a general field theory that he had been elaborating for the last 40 years of his life. The full comprehension of the role of space images began when the theory of elementary particles started to be elaborated on the basis of field concepts.

The paradox is that, while the World of physics opens up through the image of space, this image itself is revealed only partially. And this is not surprising: the concepts of physical space become clear only as physical hypotheses are constructed.

One thing seems to be clear: the Newtonian conception of absolute Space and Time existing as a universal ontological reality that reigned unconditionally up to the end of the nineteenth century seems at present extremely naive. There is a temptation to express a viewpoint to a certain extent resembling the Leibnizian conception of Space and Time not as a substance, but as an order of things and events.[5] If anybody now still wishes to assert the substantial existence of Time–Space, this should be done with caution. The above-mentioned book by Angel (1980) in which an attempt is made to comprehend relativity theory philosophically ends with the following laconic phrase: "Space–time does exist" (p. 252).

The possibility of this assertion is revealed only after the absolute and relative aspects are introduced into consideration. For Space–Time, absolute aspects are such manifestations as dimensions,[6] continuity, and

[5]At the end of the nineteenth century Mach made an attempt to revive this viewpoint.

[6]I already mentioned above that the three-dimensional nature of Space and, therefore, the four-dimensional nature of Space–Time variety may be regarded as one of the fundamental principles of the Universe. This assertion is not, however, unconditional. For example, Vertosik (1978) assumes, side by side with the four-dimensional variety, a five-dimensional variety of a geometric model allowing us to stratify all the types of physical interactions. Edmonds (1975), considering the inner dynamics of particles, gives a five-dimensional generalization of the general relativity theory, identifying the fifth dimension with cosmic Time. A brief exposition of other papers discussing the problem of Space–Time from the standpoint of contemporary physics may be found in the analytical review by Panchenko (1980), as well as in the book by Barashenkov (1979).

differentiability,[7] while the metric properties of Time–Space are relative. Metric is amorphous[8]: in its concrete manifestations it is not a property inherent in the space–time geometry.[9] In general relativity theory, metric is defined by the energy–matter of the Universe, and then the gravitation potential proves to be represented by the Space–Time metric tensor. Increase in complexity of the concept of physical Space can be found in the paper by the American scientist J. Wheeler. He created a new direction, *quantum geometrodynamics*, that considers physical objects and their properties as specific manifestations of the curved space with various topological properties. In quantum geometrodynamics, geometry loses its familiar static character (Wheeler, 1968).[10]

> *Geometry at short distances fluctuates to a high degree.* This idea opens up mainly new ways of research on the nature of an electric charge, vacuum and elementary particles. (p. 39)
>
> If this general reasoning is true of the geometry fluctuations the way topology and curvature of space are variable, this conclusion is crucial for the physics at submicroscopic distances and for the physics of superspace. Superspace should be expanded from the positively defined 3-geometries[11] having one topology up to the aggregate of positively defined 3-geometries which are, in their turn, characterized by the aggregate of different topologies. . . . Short-distance geometry fluctuates not only from one kind of curvature to another, but also from one kind of microtopology to another. (p. 41)
>
> Quantum fluctuations of geometry give rise not only to the new vision of the nature of electricity and vacuum fluctuations of energy, but also produce a new conception of elementary particles as excited quantum states of space geometry. (p. 48)

And while the concept of the fluctuation of metrics is perceived easily enough, the concept of fluctuating topologies requires some explanations:

> To gain the new comprehension of electricity, it suffices to doubt the old conception of our space topology: "Short-distance geometry is Euclidian." This idea is only true for the everyday experience. The person flying over the ocean at the height of several miles sees the ocean

[7]Differentiable manifold may be represented as a homogeneous and continuous arrangement of points on which various differentiable points can be defined.

[8]This assertion is discussed in detail by Grünbaum (1963).

[9]Here an analogy seems relevant with a probabilistic measure. The latter in its concrete manifestation is not a property of the probabilistic space either. It is introduced by an observer. Those are two different but related ways of giving a numerical measure on a space.

[10]I could not find the English version of the book and so had to translate the quotations from German. Pages are indicated according to the edition in German.

[11]The concept of superspace introduced here is the stage for geometrodynamics. Says Wheeler, if the momentary configuration of a particle is an event set by an individual point in space–time, the momentary configuration of space is 3-geometry acting as an individual point of superspace.

as a plane, i.e., it has the Euclidean topology. However, a person in a boat amidst the ocean waves sees it in quite a different fashion. He sees around himself constantly forming and breaking waves. He also understands that at a distance of centimeters and millimeters the water surface is even more complex and multiple-connected. The rough ocean is the best analogy for geometry at distances in the order of the Planck distance where there is not a single calm region. (p. 39–49)

The concept of a space resonating between different foam-forming structures is a major new step. (p. 68)

I earlier proceeded only from the variability of the metric of the morphophysiological attributes of space. Perhaps I should go even further and speak of the fluctuation of topologies? Wheeler underlines that topology is primary and metric is secondary. The distance between A and B will be, in the long run, determined by the topological notions, by the ramification of interrelations between A and B. Perhaps, we shall even succeed in describing much more finely the vibrating harmony of the multi-bounded animate World that strikes us as something unusual, if it is derived only from the fluctuation of the space topology.

However, a question would seem relevant as to how deep theoretical biology of the future will be able to submerge itself into modern, highly abstract, and therefore pathological (from the viewpoint of common sense) structures of contemporary geometry? Akchurin (1973), a Soviet philosopher of science, approaches this question from a somewhat different direction:

. . . all the phenomena of life also represent an extremely complicated space and time correlation of certain physico-chemical processes, "organically integral" just because, to our mind, specific structures "enter the game," that "glue together" space-time points of contemporary algebraic geometry. (p. 209)

What he refers to is Grothendieck's space where points can locally stick to one another, glue together and stop being closed, separated from one another.

However, all those statements are of too general a character. The following illustration from biophysics considered by Manin (1980) seems much more concrete:

Classical continuous systems governed by differential equations can imitate discrete automata only if their phase space is of an extremely complicated structure: with a lot of regions of stability divided by low energetic barriers. . . . However, we often try to describe the functioning of "genetic automata" in such mechanical terms. Such a description leads to a number of paradoxes, the most famous of them being the

> hypothetical picture of unwinding of the double spiral in the process of replication. In this picture the double spiral of the bacterial chromosome is wound about 300,000 times. Since under favourable conditions it is doubled in 20 minutes when the spiral unwinds the part of the chromosome must rotate with the rate no less than 125 revolutions per second. And simultaneously an intricate net of faultless biochemical transformations must take place. (p. 15)

We seem to be able to comprehend the situation if the conception of geometry is expanded the way Wheeler does it. To characterize it, he introduces, besides topology, differential structure and metric, the concept of spin describing "the relation[12] of position-turn" of the figure in space. Then the possibility opens up to consider more capacious, multilayer spaces with 2^n possible spin structures in the n-bound space (Wheeler, 1968).

However, it is difficult to imagine the possibility of an independent ontological existence of many different Spaces. It would be better to speak of different geometries as different grammars necessary to produce various texts of the World. The unity of the World will be defined by all its texts being arranged so as to be derivable from the grammars of geometries. Geometries exist so far as there exists an observer perceiving the texts they produce.

5

What can be the role of the observer in constructing a theoretical biology? We know too well that in physical theory the role of the observer is far from being trivial. Perhaps it is even possible to state that physical theory is constructed as a specific dialogue between an abstract observer and the reality that exists just as it is, not being manifested in any other way. In any case, already in classical mechanics, in order to record the motion equations, an abstract observer must be given the space geometry and shown the way to set points on this space. Relativity theory introduces the concept of the accelerated observer who has a ruler and a watch and introduces in his neighborhood the system of readings (Misner, Thorne, and Wheeler, 1973). In quantum mechanics, matters are even more complicated. It deals with the quantum state of a system that, though unobservable, has an independent existence. Observation is regarded as interaction between this system and the observer, the apparatuses. As a result of the interaction, what had earlier existed as a statistical potentiality now becomes actualized. The description for the ensemble of outcomes is

[12] Wheeler explains the meaning of this relation as follows: take a cube and fasten its vertices with elastic cords to the corners of the room and select the axis of rotation. Rotate the cube around this axis for 360°. The cube will return to its initial position but the cords will not—they are now twisted. Thus, the interrelation between the cube and its environment is not completely determined by its position.

fairly clear. But how can an outcome of a single experience be predicted? Perhaps here the existence of a latent metaobserver should be assumed who makes the choice while being limited by statistical potentiality?

It seems relevant to continue here the comparison of the two realities, semantic and physical, suggested by Wheeler (1981). They both are revealed in an experiment carried out by the observer in the situation of some uncertainty. Within our system of concepts, the semantic reality—the meaning of the World—is revealed only after the Text is constructed and its meaning is perceived by the observer capable of producing a comprehension filter $p(y \mid \mu)$. This filter is unpredictable: it does not exist within the observer beforehand but emerges as a result of his interaction with the Text (Nalimov, 1981a). The reality of quantum mechanics is revealed in a similar way. Here is what Wheeler says in comparing the physical experiment with a peculiar semantic experiment described by him and directed at revealing the verbal meaning:

> Similarly, the experimenter has some substantial influence on what will happen to the electron by the choice of experiments he will do on it; but he knows there is much unpredictability about what any given one of his measurements will disclose. (p. 92–93)

Then Wheeler emphasizes the following statement by Bohr concerning the physical reality:

> In the real world of quantum physics, no elementary phenomenon is a phenomenon until it is a registered ("observed") phenomenon. (p. 93)

In my model, when resorting to geometrization, I say that morphogenetic attributes are ordered somehow or, better, relative to the numerical continuum. Here, if you like, Nature acts as an observer realizing this correspondence. Further, I speak of the distribution functions: in the contemporary Bayesian interpretation, this is nothing more than a measure given on a set by the observer whom again we can identify with Nature itself. If we now turn to the existing biological theories, e.g., to Darwinian evolution or to modern synthetic theory of evolution, we get an impression that they easily operate without discussing the role of the observer. At the same time we know that in the living World man has for ages been an active observer able to create new texts of Nature. Earlier he did it by means of natural selection. Now there has appeared a more powerful and threatening (due to its unpredictability) tool: genetic engineering. Here lies a paradox: physicists are incapable of doing anything of the kind; they cannot create new physical Worlds though we all are sure that the physical World is less complicated than the animate World and is incomparably better comprehended theoretically.[13] And while physical theory allows the existence of an abstract observer always acting according to some conception, in biology there acts a real conception-free observer. He is ready to act as a Demiurge, the creator of a new World.

6

What is the role played by number in the structure of the physical World and the living World? Here I have attempted to say a few things about it, but this is, of course, only a beginning.

What is the analogue of Heisenberg's uncertainty principle for the living World? The uncertainty principle is the fundamental assertion of quantum mechanics: a physical system cannot be in states in which its center coordinates and impulse take some definite values. The product of two uncertainties in the order of magnitude should be not less than Planck's fundamental constant. The more definite the value of one variable, the less definite is that of the other. In the limiting case, when one value is known for certain, the other reaches infinity and loses its meaning. What in biology can be compared to this precise, quantitatively given definition of uncertainty in physics? In biology the most precisely given unit is the initial taxon, namely, a species. There is interspecific uncertainty. It may be very serious: there even exists a catalog for plant deformities. However, biological science is unable to give a quantitative measure of uncertainty, though this problem here seems to be no less serious than in the physics of the microworld. For the construction of theoretical biology, it would be important to understand why biological changeability cannot be limited by a numerical relation. The simplest answer is: there are not and cannot be any fundamental constants in biology. Otherwise, the changeability of biological systems is such that it is describable only through the measure distribution, without indication of limitations in distribution function variance. Biology is more statistical than physics.

7

What are recognition and memory? In the living World both of these phenomena are strikingly clearly and at the same time enigmatically manifested in immunology (Micklem, 1977). How does recognition occur if

[13]The paradox can, perhaps, be solved as follows: a physicist wishing to create a new World must do the unthinkable: change the values of fundamental constants; a biologist does not have to do that. In a purely hypothetical way it may be assumed that biologists wishing to create a new world can be set quite an unusual task exceeding the boundaries of genetic engineering. I already said, referring to Morowitz, that the entire living world, despite its tremendous variety, is composed of a very small set of initial combinations. Can life be made of other matter which biochemists now have at their disposal? And if so, what it would look like? Anyway, theoretical biology will have to mature to this problem.

there are no two similar individuals within a species? In what way are the results of recognition retained in memory? Is at least a vague analogy possible with such concepts of physics as the paradox of Einstein-Podolsky or, even broader, with the concept of the quantum ensemble and quantum non-locality[14] as well as of the Neumannian theory of the recognition of a slit by the elementary particles approaching it. Note that the concept of the coordinated action turns into a paradox both in the animate World and in the inanimate World. As to recognition proper, this is an important psychological and now even a cybernetic problem. People have been interested in it from time immemorial.[15] In cybernetics it emerged with respect to the problem of pattern recognition which is in no way an easily solved problem.

The list of comparisons and juxtapositions could be continued, but this does not seem to be necessary. Something else is more important: to make a similar comparison and juxtaposition between the problems of biology and psychology. The stumbling block will be the concept of consciousness. We are accustomed to assuming that consciousness is linked with highly organized matter. But how can highly organized matter manifest a property completely foreign to its lower forms? Is it possible to acknowledge that something is produced from nothing, or is it more reasonable to assume the omnipresence of certain reduced forms of consciousness or, better, the existence of pre-consciousness? The journal *Foundations of Physics* from time to time publishes articles that either make use of the rudiments of consciousness in the physics of elementary particles (Cochran, 1971), or interpret non-trivially the dichotomy "consciousness versus matter" as set by the problems of quantum mechanics and relativity theory (Stapp, 1982). Physicists conduct conferences devoted to the interaction between consciousness and matter.[16] As far as I can judge, at present in the living World it is possible to speak not of the instrumental fixation of the rudimentary forms of consciousness (sometimes called a "biofield" or "morphogenetic field")—here an unambiguous experiment jeopardizing the hypothesis is hardly possible at all—but of the elaboration of a general theoretical conception having a sufficient explanatory power to account for

[14]Non-locality, according to the well-known physicist Bohm (Bazhanov, 1981), also takes place in macrophenomena: in the hyperfluid helium far apart atoms are correlated.

[15]It seems relevant here to remind the reader of the dialogue between the Greek king Milinda and the Buddhist teacher Nagasena (second century B.C.). It deals with the problem of recognition, e.g., how it is possible to identify a chariot (Milinda phanda, 1964): "If you, sire, came by chariot, show me the chariot. Is the pole the chariot, sire?" And Nagasena turns the King's own argument against him. The chariot is neither the pole, nor the axle, the wheels, the body, the flag-staff, the yoke, the reins, nor the goad. It is not a unity of all those parts or something apart from them that constitutes a chariot. "I do not see the chariot. . . . You, sire, are speaking an untruth, a lying word. There is no chariot."

[16]I mention here three of them: in Cambridge, England, in 1978 (Josephson and Ramachandran, eds., 1980), in Houston, Texas, in 1979 (Jahn, ed., 1981), and in Cordoba, Spain in 1979 (Thuillier, 1980). Among the participants were the outstanding physicists Josephson, Wigner, and Wheeler.

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the already existing variety of facts that do not fit purely mechanistic constructions.

Contemporary science seems to reject everything that cannot be explained within the frame of the existing paradigm. For example, is it not a striking fact that despite numerous investigations no physiological property has so far been discovered which would allow us to define the state of hypnosis. Yet the hypnotist is able to induce a skin burn on the hypnotized person, which can be medically diagnosed (Chertok, 1979). We are dealing here with the influence of one person's will on the skin (which is far from being a highly organized matter) of another person. The action is mediated by the extinguished consciousness of the person under hypnosis. Man is viewed as an extraordinary psychosomatic entity linking consciousness with seemingly unconscious matter. How can that be? Can biological science claim to be complete if it ignores such phenomena? Nevertheless, such phenomena are undoubtedly worthier objects of study than the notorious telekinesis which can hardly be studied by scientific methods, though its proponents strive to do so. Is it not time to make a compendium which would gather all the physical and biological phenomena that cannot be explained or are only poorly explained without employing the concept of existence of intermediary forms of consciousness (or pre-consciousness) linking the World?

However, everything has been said here not from the standpoint of a biologist but from that of a logician acting as a metaobserver. The reader may see it both as an advantage and a disadvantage on the part of the author.

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Chapter 6

Conclusion as Metaphysics of the Above Reasoning

I feel like breaking the prohibition made by Wittgenstein and speaking whereof one must be silent[1]: Why does entity exist ànd nothing exists not? In terms of Heidegger (1961) this is the shortest formulation of the basic question in classical German metaphysics.

This formulation has amazingly much in common with the basic philosophical idea of Einstein. Here is what Wheeler (1968) said about Einstein:

> His long-cherished dream that remained unrealized during his lifetime and whose realization has not so far been approached closely enough, can be expressed by the ancient dictum *Everything is Nothing.* (p. 1)

But what exists and what does not exist? Whence comes what there is and what there is not? Why is existence given through negation ànd negation through existence? Only a few alternatives can be proposed to answer this question.

1. Creationism. This idea lying at the source of Western culture is still strikingly alive. Even now it is ready to oppose mechanistic evolutionism (see, e.g., Clark, 1980). If the Old Testament husks are thrown away, what remains is the uncreated Demiurge existing outside Time and therefore not existing, who creates in Time which, perhaps, does not exist. Here everything is at the same time vague and clear since nothing is explained. There is nothing to be understood.

2. Evolutionism in its traditional sense. In scientific terms the idea of evolutionism sounds roughly as follows: there exist, out of Time and created by nobody or nothing, fundamental laws and equally fundamental con-

[1]The *Tractatus* by Wittgenstein concludes with the line: "Whereof one cannot speak, thereof one must be silent." However, now I would say that a philosopher is a person who speaks about what he should keep silent about.

stants that create the World and Life within it, that bring the World to collapse and revive it anew according to the only possible pattern. Logically, traditional evolutionism does not differ radically from creationism. Perhaps it is even possible to assert that evolutionism is the explication, by expanding in time, of the idea of creationism, and to assume that the Genesis is nothing more than a vague guess, expressed metaphorically and needing no explication.

The idea of *evolutionism (in its broad sense)* seems to be more meaningful than that of creationism and, therefore, it contains more facts to be understood. If such Laws exist, then there should exist a language to express them. There are reasons to believe that this language should be finite and determined, and at the same time it must be sufficiently rich logically, e.g., like that in which the arithmetic of natural numbers is expressed. However, such a language stumbles over the Gödelian difficulty. It is enough to dilute determinism with a mechanistic randomness of this kind, as was done by Monod (1972), to make all entities not only possible but also comprehensible? What do we know of the ontology of chance? Where is the random generator located?[2] What are its statistical characteristics? Was it created or is it as eternal as the Laws are? Are we not trying to wed the Old Testament Demiurge with the dancing Siva by softening the Laws with Chance?

However, the ideas of creationism are not only incomprehensible, they are also unrepresentable. Laws should have existed when nothing else had existed or when everything had already collapsed. They had to exist unformulated or formulated in the language which could not exist and then inscribed on the non-existent tables of the non-existent Moses.

There is another difficulty in comprehending traditional evolutionism. Being set by the Laws, evolution should lead to something. We should be

[2]Recall that computer generation of a random numbers sequence is a sufficiently serious problem (Zhurbenko et al., 1983). Random numbers generated by a computer are never random enough. We constantly hear warnings that during a computer simulation fine effects may be due to the fact that we actually deal with pseudorandom numbers with fuzzy periodicity. How can all this be correlated with the concept of randomness in biological evolution? At present, no universal and all-embracing definition of what a random value is can be given. When we speak of a random value we imply that it is random in some definite sense (Nalimov, 1981b). And in what sense is a mutation random? It seems possible to speak of two levels of randomness. The first one is the emergence of a random number related to the sequence of numbers with a given distribution and definite kind of the generator of randomness having a selective (non-rectangular) spectral density $F(w)$ setting the fuzzy periodicity (statistical connection) of the numerical sequence. The second level of randomness is the spontaneous emergence of the randomness generator itself and the corresponding spectral density $F(w)$. Traditionally, a researcher making use of the concept of randomness proceeds from the first kind of randomness ignoring the statistical connection of the sequence of a random value realization. My reasoning is based on randomness of the second kind. We might describe the spontaneous emergence of the filter $p(y|\mu)$ in a schematic way as follows. After the evolutionary impetus y in nature there emerges a new generator of randomness y with its inherent spectral density $F_y(w)$. Nature can interpret the frequency continuum w simply as a numerical continuum μ, on which the entire variety of morphophysiological attributes is given. This is how the distribution function emerges that is recorded in Bayesian terms as $p(y|\mu)$.

able to evaluate this goal orientation by proceeding from our knowledge of the Laws, no matter how incomplete it is, or from an approximate, qualitative extrapolation of the evolution curves. This includes few possible alternatives: (A) the first is infinite evolution, which is hardly imaginable; (B) the finite point of the supreme harmony may be achieved or at least an asymptotic drive toward it may be noticed; (C) periodicity or quasi-periodicity can be discovered related to collapse and revival; (D) the last alternative is irreversible destruction.

And while the evolution of the physical World seems to go along the lines of alternative C, for the evolution of life on Earth we have to accept possibility D. The evolutionary Laws are structured so that they are directed at momentary (on the cosmic scale of time) representation of life as a phenomenon parasitizing on the Earth and destroying it. There is a lot of think about here.

3. **Evolutionism as spontaneity.** This is non-existence of the entity in its spontaneously unpackable unpackability. Everything cannot but exist within what is unpacked, as the continuum is unpacked. But in what is unpacked through probabilistically weighted fuzziness, nothing can exist since it contains everything. Time is a measure of changeability emerging during unpacking. But if there are many times and we do not know how many they are and what they are for, that means there is merely no Time at all. And if there is none, there is nothing to speak about.

If there is no Time, if nothing exists, but entity does exist, then nobody could create anything. The problem of creation is thus removed. Thus the principal potential objection against the existence of the semantic field disappears. Its existence is not distinguished from non-existence. This is a semantic vacuum that remains when nothing exists, when it is not manifested and, therefore, does not exist. There remains only spontaneity of unpacking. That is exactly the *entity* which exists when nothing exists. Nature exists in its spontaneity. Man exists while he is capable of spontaneity. Spontaneity is Existence itself.

Here my assertions start to have strangely much in common with the Taoist philosophy. I quote Watts (1975) on the principal concepts of Tao:

> There is, first of all, the Tao—the indefinable, concrete "process" of the world, the Way of life. The Chinese word means originally a way or road, and sometimes "to speak," so that the first line of the *Tao Te Ching* contains a pun of the two meanings: The Tao which can be spoken is not eternal Tao. (p. 35)

Further Watts quotes Lao-Tsu,

> The Tao is something blurred and indistinct.
> How indistinct! How blurred!

Yet within it are images.
How blurred! How indistinct!
Yet within it are things.
How dim! How confused!
Yet within it is mental power.
Because this power is most true.
Within it there is confidence. (p. 36)

Hence the Tao concept of the spontaneous arrangement of the Universe becomes clear:

> Because the natural universe works mainly according to the principles of growth, it would seem quite odd to the Chinese mind to ask how it was made. (p. 36)

Evolution outside the Law, outside the familiar Substance created from our comprehension, outside the Creation. Evolution as spontaneity and nothing else. The striking fact is that, proceeding from the Western concepts, we revolt against its own fundamental structures and quite unexpectedly we come to the Oriental outlook of the Universe. We get into one level with the assertions of the American physicist Capra (1975). Western thought turns to be extremely versatile and dialectical: it implicitly contains Eastern thought as well.

Spontaneity is sometimes manifested through measure. The entity proves to be a numerical principle, while the Universal consciousness is a measure. Ancient thinkers gave the Great Consciousness different names: *The Great Silence, Tao, the Absolute* which may be defined only apophantically. Number taken by itself is Silence. But Number taken as a probabilistic measure helps to unpack the semantics of the World packed on the numerical continuum.

Spontaneity is recognition (or, otherwise, understanding) of what is packed on the semantic continuum.

> . . . understanding (vignana) was Brahman, for from understanding . . . beings are born; by understanding, when born, they live; into understanding they enter at their death. (Upanishads, 1965, p. 63)

The World is dialectical, its unpacked meanings are ephemeral within it. They are not substantial. They are born in spontaneity and into spontaneity are they gone, leaving an invisible trace behind.

Spontaneity is the Incomprehensible.

Spontaneity is what acts through Measure, not through Law.

Spontaneity is Freedom of the World.

Spontaneity is Love.

Spontaneity is Gnosis, revelation of meanings, their extraction from Non-Existence.

Spontaneity is Man himself.

Spontaneity is Entity.

Spontaneity is the Potentiality of the World.

What has been said above sounds like a myth. Indeed, making use of a probabilistic ontology, we revive the ancient myth. Within the European tradition it is rooted in pre-Socratic reasoning; in the East it goes back to Hinduism and Taoism. European science did not accept the myth of the World as a spontaneously unpacked totality. Perhaps now science, or at least philosophy, will be ready to enact this old karma rejected by the all-triumphant belief in the mechanistic order dictated by simple, easily comprehensible laws.

Let us try now to embrace by a single glance what has been said above. I would not like my approach to be perceived as "extranihilism." My attitude toward a Cartesian-Newtonian mechanistic background on which evolutionary ideas keep developing is, indeed, acutely critical. But the major point is the positive aspect, the possibility to show the legitimacy of the probabilistic, or, actually, geometrical ontology of the World, whose motive power is not a law, but a spontaneity that acquires scientific contours when recorded in the language of model notions. Spontaneity becomes the fundamental principle of the World. We cannot reduce the nature of spontaneity to other scientific notions. They are still not fit for it, though already physics seems to need a law-like concept of spontaneity.

We are even ready to acknowledge that the basis for spontaneity is our ignorance.[3] But we should be aware of the fact that science, striving for the mastery of the World, has always achieved success when formulating hypotheses inspired by ignorance! We evaluate highly modern physics precisely because it has expanded the horizons of our ignorance. Can it be in any way compared with that of a hundred years ago? Perhaps one can say that the new knowledge emerges as a response to the ignorance that we began to be aware of. Mathematical formulation of the concept of spontaneity is a step towards the awareness of ignorance connected with the lack of comprehension of what a creative process is. I recently read an article by Nielsen (McCrea and Rees, eds., 1983, pp. 261–272), a Danish theoretician, which emphasizes the extreme complexity of the physical world and proposes for consideration a probabilistic ontology:

> The picture of physics that I have in mind in this project of random dynamics is the following. There exists some system of fundamental

[3] I denote by this word what goes on in the dimensions of reality so far unattainable for our intellectual perception.

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> physical equations (or a fundamental action or the like) governing the time development of some fundamental fields. It may be difficult to say exactly in what terms it should be formulated, and it is part of my point that it may not be important to know this. Contrary to the speculation—which many physicists believe—that fundamental physics is simple, these fundamental equations are assumed here to be extremely complicated. Because of the high degree of complication assumed of the fundamental equations (the fundamental laws of nature, we could say) we have to give up any hope of guessing their exact form. Our best hope is, then, to guess a very large class of possible fundamental equations (or actions) and a probability measure over that class. It would then make sense to assume that the actual fundamental equation system (or action or whatever) is randomly chosen from that class in the sense that after having added assumptions about how to connect the fundamental fields (degrees of freedom) to experimental observations one would find agreement with experiment within statistically expected accuracy. (p. 262)

And while we set the probabilistic measure on a field of morpho-physiological attributes, in the world of physics it proves to be set on a field of differential equations.

My presentation here can in no way be regarded as an attempt to construct a new conception of biological evolution. It lacks the profound elaboration that would allow us to apply the verification principle, or, in terms of Popper, test its falsifiability. Rather, it is but an attempt to sketch philosophical premises for a new research program. But are they sufficient?

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