George S. Levit

BIOGEOCHEMISTRY – BIOSPHERE – NOOSPHERE

The Growth of the Theoretical System of Vladimir Ivanovich Vernadsky

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Contents:

1. INTRODUCTION

1.1. *Vladimir Ivanovich Vernadsky: Scientific Biography*

Vladimir Ivanovich Vernadsky (1863-1945) is one of the greatest Russian naturalists. He is regarded as one of the founders of modern geochemistry, biogeochemistry and a pioneer of radiogeology. In disciplinary terms he was also an expert of genetic mineralogy and one of the outstanding Russian crystallographers. As a person of encyclopaedic knowledge he is also regarded as one of the great thinkers of history and philosophy of science. He was the founder (1932) of the Institute of History of Natural Sciences and Technique of the Academy of Science of the USSR. In his works he tried to combine the different branches of science, to elaborate an interdisciplinary approach to the problems of natural sciences involving all actual investigations in the different branches of science and science history.

The most valuable contribution to modern science of Vernadsky is, plausibly, his theory of the biosphere. The author of the contemporary Gaia-theory James Lovelock wrote: „we (Lovelock himself and a biologist and co-author of Gaia-theory Lynn Margulis - *G.L.*) discovered him (Vernadsky) to be our most illustrious predecessor" (Lovelock, 1986, p. 51). In other place L. Margulis (1995, p. 47) added: „Indeed, Vernadsky did for space what Darwin had done for time: as Darwin showed all life descended from a remote ancestor, so Vernadsky showed all life inhabited a materially unified place, the biosphere".

Krumbein (1996) in his approach to the field of life as an expression of the intimate relations of the geological system of Earth with its biological mega-ecosystem expressed the view that Vernadsky was intuitively analysing the power of life without knowing much about molecular ecology.

Vernadsky was born in 1863 in Sankt-Petersburg. His father Ivan Vernadsky (1821-1884) was a professor of economics and statistics in the Alexandrovsky Lycee. In 1881 Vernadsky entered St. Petersburg University where he was a student of as brilliant scientists as the chemists A. Butlerov (1828-1886) and D. Mendeleev (1834-1907), the botanist A. Beketov (1825-1902), the soil scientist and mineralogist V. Dokuchaev (1846-1903), the zoologist N. Wagner (1829-1907) and the physiologist I. Sechenov (1829-1905). The most influential of Vernadsky's teachers was V. Dokuchaev who became a supervisor of his magister and doctor theses. Dokuchaev was the founder of a set of natural sciences. First of all, he created a scientific paradigm of the modern soil science and founded contemporary genetic pedology considering soil as a product of the interactive effects of all different environmental factors. Dokuchaev founded a landscape science as a part of physical geography and created a concept of the natural climate related zones. Moreover, it is recognised now (Timofeief-Ressovsky & Tjurjukanov, 1966) that he was the first to declare the necessity of a new synthetic science for studying „the genetic, eternal and always lawful connection existing between the forces, bodies and phenomena of mortal and living nature" (Dokuchaev, 1898). Thus he can be also regarded as a fore-runner of Vernadsky's theory of the biosphere.

In 1885 Vernadsky completed his examinations for the degree of candidate of science in mineralogy and 'geognosia'. In 1888 he left St. Petersburg. He decided to study crystallography under the supervision of the German scientist Paul Groth (1843-1927), who was Professor of Mineralogy at the University of München. Vernadsky also took an advantage of the presence of L. Sohncke (1842-1898) in München who was working on the theory of crystallisation (Bailes, 1990, p. 38). Sohncke evidently influenced

Vernadsky who mentioned Sohncke even in the latest period of his creativity when working on his space-time theory.

In 1889 Vernadsky moved from München to Paris where he started to work simultaneously with the chemist H. Le Chatelier (1850-1936) and the mineralogist F. Fouqué (1828-1904). Le Chatelier helped Vernadsky to find a dissertation topic and as Vernadsky later recognised significantly influenced his scientific work. Le Chatelier was working with the problem of crystalline polymorphism and indirectly influenced Vernadsky's biosphere and space-time theories.

In 1890 Vernadsky returned to Russia because A. P. Pavlov (1854-1929) Professor of geology at Moscow University encouraged him to apply for a teaching position.

In 1891 Vernadsky completed the magister dissertation and in 1897 submitted the doctoral dissertation in crystallography titled „*On the Planes of Gliding*". In 1902 he became a Professor of mineralogy and crystallography of Moscow University. In 1903 Vernadsky published his first major scientific book „*The Fundamentals of Crystallography*". However, it was not crystallography that made him a well known scientist. As K. Bailes calculated only about seven percent of his books and articles was devoted to the study of crystals per se (Bailes, 1990, p. 69). In those times Vernadsky also wrote and published his first major article in the field of history and philosophy of science „*On a Scientific Worldview*" (Vernadsky, 1902).

Investigating the history of minerals of the Earth's crust Vernadsky came to the idea to study the paragenesis of chemical elements. Already in these years Vernadsky founded a new scientific school detached from mineralogy and soil science. At that time the American scientist F. W. Clarke (1847-1931) developed similar ideas which he published in his „*Data of Geochemistry*" in 1908. However, in contrast to Clarke Vernadsky paid a lot of attention to the role played by living matter in the history of the Earth's crust and the atmosphere. In 1909 Vernadsky made a report to the Meeting of the Russian Naturalists and Physicians about the basic principles of a new science - *geochemistry* (Aksenov, 1994, p. 111). Vernadsky's student A. Fersman (1883-1945) gave the first regular course of general geochemistry already in 1911 (Vernadsky, 1988[1], p. 345).

At the same time Vernadsky was beginning to work in the field of radioactivity. In 1908 Vernadsky took part in the conference sponsored by the British Association for the Advancement of Science (he was a member of this Association since 1889) where he met John Joly, one of the pioneers of the radioactivity research. Vernadsky was deeply impressed by the report of Joly and already in 1909 organised the first radiological laboratory in Russia.

In 1911, in protest against political repressions, Vernadsky resigned together with other lecturers and professors of Moscow University from his position. After his resignation Vernadsky moved to St.-Petersburg where he headed the newly established mineralogical laboratory of the Academy of Sciences (Krout, 1983). One year later Vernadsky was elected as a an ordinary member of the Academy of Science.

As early as in 1912 Vernadsky published an important article „*On Gaseous Exchange of the Earth's Crust*", where he emphasised that almost all of the Earth's gases are biogenic and involved in the cyclical processes. One has to keep in mind that these ideas were publicised world-wide only in 1970-s by J. Lovelock with colleagues (e.g.: Lovelock, 1972, 1979; Lovelock & Margulis 1974). Thus Vernadsky turned his mind on biological phenomena, but in contrast to the general biological approach he was beginning to think of life from the viewpoint of geology. Instead of the then existing vague concept of life he started to elaborate his concept of „living matter".

In 1910 Vernadsky visited Eduard Suess (1831-1914) in Vienna. Suess was the first scientist to use the term „biosphere". Already in 1911 this term appears in the works of Vernadsky although without definition.

In 1914 the First World War broke out. Russia was short of some strategic minerals, which had been supplied by Germany until then. In 1915 Vernadsky organised and headed the Commission for the Study of the Natural Productive Forces of Russia (KEPS). KEPS later laid the foundations for many scientific institutions.

In 1916 Vernadsky was working with biological literature and started to elaborate the basic principles of biogeochemistry. In the spring of 1917 Vernadsky was told by his physician that he was suffering from tuberculosis and advised to leave Petrograd (St. Petersburg). During his short stay in the Ukraine, in the calmness of his Datcha „Shishaky", Vernadsky started to write the book (first ed.:Vernadsky, 1978) about the role performed by living organisms in the geological history of Earth (Sytnik et. all, 1988, p. 31). After the October revolution (1917) Vernadsky moved to Kiev where he took part in organisation of the Ukrainian Academy of Sciences. He was elected as the first president of this Academy in 1918. In the same year he initiated several biogeochemical scientific investigations. At the initial stages of this work Vernadsky formulated the following tasks (Lapo & Smyslov, 1989, p. 55): 1) to calculate a quantitative elementary composition of the different species; 2) to investigate the geochemical history of silicon, copper, zinc, lead, silver and some other elements; 3) to determine some other geochemical characteristics of living organisms like the average weight and water content as well as the percentage of carbon in the organisms.

The first biogeochemical laboratory in the history of natural science was opened on the base of a sugar plant laboratory. Vernadsky with assistants detected nickel in the tissue of mouse and nickel and cobalt in lichens. Vernadsky aimed at the creation of biogeochemical tables of different elements for different organisms following the example of F. M. Clarke who had created such tables for various types of minerals (Bailes, 1990, p. 145). The experiments in this lab and in the lab of Kiev University showed, for the first time, that cyanobacteria perform an important role in the decomposition of the kaolin core of clay minerals.

In the summer of 1919 Vernadsky worked on the Dniepr biological research station determining the quantity and chemical composition of various species in certain districts. One of Vernadsky's research assistants on the Dniepr station was Feodosij Dobrzhanskij (Vernadsky, 1994[2], p. 253) later one of the founders of the synthetic theory of evolution known as Theodosius Dobzhansky. K. Bailes reports (1990, p. 145) that during these months a nineteen-year-old student (Dobzhansky) walked twelve miles from Kiev once each week with a knapsack of mail and groceries. Dobzhansky was deeply impressed by the work with Vernadsky and in 1921 he wrote to Vernadsky: „To work with You is nearly happiness to me" (Dobzhansky, 1990). During his stay in USA Dobzhansky kept always in contact with Vernadsky's work. In his *„Genetics of the Evolutionary Process"* (1970) Dobzhansky quoted Vernadsky's *„The Chemical Structure of the Earth's Biosphere and Its Environment"* (1965) which Vernadsky considered the summation of his life's work.

The needs of the Academy of Science forced Vernadsky to leave Kiev for Rostov. However, the hardships of the civil war confused his plans and he arrived sick with typhus at Jalta (Crimea) via Rostov, Novorossiysk and Pheodosia in the Winter of 1920. The Crimea of those times had become a refuge for many outstanding scientists like the physicists A. Ioffe (1880-1960) and I. Tamm (1895-1971) or the geologist V. Obruchev (1863-1956). All of them taught in the new Tauride University in Simferopol.

Vernadsky was also teaching in this University and in September of 1920 he was chosen as the new Rector. But already in November the Bolsheviks came to the Crimea and Vernadsky was ordered to leave Simferopol for Moscow. In Spring of 1921 Vernadsky returned to Petrograd and was promptly arrested by the Cheka (Emergency Commission). The closest friend of Vernadsky the academician-orientalist and permanent secretary of the Academy S. F. Oldenburg (1863-1934) and other outstanding personalities supported Vernadsky and he was released from prison.

After this Vernadsky continued research at the Murmansk biological station. As a result of this work Vernadsky published the article *Living Matter in the Chemistry of the Sea* (1923) where he for the first time represented his notion of *living matter*.

In 1921-22 Vernadsky organised the Radium Institute based on his radiological laboratory in the Academy.

In December of 1921 Vernadsky received a letter from Rector of the Sorbonne (University of Paris) with an invitation to teach a course on geochemistry. In July of 1922 Vernadsky arrived in Paris. His lectures were attended by two young scholars, the palaeontologist P. Teilhard de Chardin (1881-1955) and the mathematician and philosopher Edouard Le Roy (1870-1954). This meeting was very important both for Vernadsky and for Teilhard and Le Roy (see 3.1.). Based on his lectures at the Sorbonne Vernadsky published the book *La Géochemie* (1924) which was later translated to German (1930). Vernadsky worked in France until November 1925. Vernadsky had used this time very fruitfully. Besides the lecturing and publishing of *La Géochemie*, he conducted research on the radioactive mineral curite for the institute of Marie Curie. Supported by the foundation of R. Rosenthal (a French „pears king" of Russian origin) Vernadsky laid the base-lines of his pathbreaking book *The Biosphere* (1926). In this period Vernadsky (1923[1]) for the first time used the term „biogeochemistry" (Mochalov, 1982, p. 242). Vernadsky sets as the tasks of biogeochemistry: (1) exploring the methods of defining of mass of different living organisms; (2) making a complete chemical analysis of living matter; (3) making a complete quantitative analysis of the organic and inorganic substances containing rare elements (V, Cr, etc.); (4) investigating the role of living matter in formation and transformation of rocks and minerals.

Thus 1923 can be said to be the year of the birth of biogeochemistry (Lapo & Smyslov, 1986, 1989).

In March 1926 Vernadsky returned to Leningrad (St. Petersburg, Petrograd).

K. Bailes (1990) and E. Kolchinskij & A. Kozulina (1998) based on the archival materials of the Bakhmeteff Archive at Columbia University arrived at the conclusion that Vernadsky did make a considerable effort to remain in the West. However, he was unable to obtain permanent funding of his biogeochemical research. Vernadsky came back to the USSR realising that only there he could fulfil his scientific mission.

Back to the USSR Vernadsky published his „*The Biosphere*" (1926) which later was translated into French (1929) and in English (1998). This was the first outline of Vernadsky's theory of the biosphere. In „*The Biosphere*" he tried to show that living matter is an important geological force and that the biosphere is a regular part of a Cosmic mechanism forming the „Image of Earth".

In November 1926 Vernadsky established a Commission for the History of Knowledge (1926-32) which later, after some reorganisations, was transformed into the Institute of History of Natural Science and Technology (1946).

One year later Vernadsky read a report „*The Geochemical Energy of Life in the Biosphere*" (1928[1]) during a „Week of Russian Science" in Berlin. During this congress Vernadsky met also A. Einstein (1879-1955).

In 1928 Vernadsky published an important article „*The Evolution of Species and Living Matter*" where he for the first time introduced his views on evolution. Vernadsky emphasised that only viewing the evolution biogeochemically one can explain why some species are undergoing evolution while the other ones (persistents) are not. One should approach the problem globally taking into consideration the overall biogeochemical functions of living matter. In this article Vernadsky phrased the first and the second biogeochemical principles (BGCP's).

In the same year the official foundation of the Biogeochemical Laboratory of the Academy of Science (BIOGEL) took place. BIOGEL worked in several directions. Lapo & Smyslov (1989) describe some stages in the development of the work of the laboratory.

In the first period of work most of the BIOGEL collaborators were determining the average chemical composition of various individual species. On the next stage Vernadsky planned to determine the average chemical composition of various biocenoses. In 1931 BIOGEL began to work on the determination of rare and radioactive elements in the organisms. The laboratory also studied the role of isotopes in various organisms and different biogeochemical processes going on with the participation of living organisms.

After the method of spectral analysis had been developed, BIOGEL studied the biogeochemistry of the economically important minerals. In 1935 BIOGEL began studies of the physiological role of some chemical elements in endemic diseases. As early as June 1936 Vernadsky together with A. Vinogradov (1895-1975) made a report at a meeting of the Moscow Therapeutic Society entitled „*Geochemical Provinces and Diseases*". They concluded that the endemic diseases were restricted to certain areas, which Vernadsky and Vinogradov called „biogeochemical provinces", and that they resulted from the lack of certain chemical elements in the environment. This was revolutionary work for the therapy of diseases or epidemics based on the lack of trace elements.

BIOGEL elaborated the basic methodology of biogeochemical research, and achieved a great number of chemical analyses of living organisms. It was established that all chemical elements take part in the life processes although in differing proportions. The sum of this work was represented by Vinogradov in a series of papers *The Chemical Elemental Composition of Marine Organisms* (1935, 1937, 1944).

Among other important tasks BIOGEL constructed the first Soviet instalment for making heavy water, one pre-requisite of constructing atomic bombs.

Later the BIOGEL was transformed into the Vernadsky Institute of Geochemistry and Analytical Chemistry.

The summer of 1929 Vernadsky spent in Germany and Czechoslovakia, where he read Eddington's „*The Nature of the Physical World*" (1928) which influenced Vernadsky and turned his attention to space-time problems of living matter (Aksenov, 1994, p. 388). Already in November 1929 he made a report in the Leningrad Society of Natural Scientists titled „*The Study of Phenomena of Life and Modern Physics*" where he approached the problem of space-time biologically and introduced the term „biological time" for the first time in the literature according to our knowledge.

The summer of 1931 Vernadsky spent in Peterhof (a suburb of Leningrad) working much on the space-time problems (Aksenov, 1994, pp. 404-405). He planned to write a book „*About Life (Biological) Time*" but did not finish this work. However, in December 1931 Vernadsky made a report „*Problem of Time in the Modern Science*" which later was published (Russian version: 1932[1]; French version: 1934[1], 1935).

Simultaneously Vernadsky writes his fundamental „*History of Natural Waters*" (1933-1936). In this book he not only outlined a geological history of waters but also described the global influence of the humankind on the water resources of the planet.

In 1932-33 Vernadsky travelled in various countries including Germany, France, England, Poland and Czechoslovakia. In Münster he made a report (1932) *Die Radioactivität und die neuen Probleme der Geologie* (Radioactivity and New Problems of Geology) for the Deutsche Bunsen-Gesellschaft für Physikalische Chemie. In England Vernadsky communicated with Frederick Soddy (1877-1956) who founded a theory of isotopes. The study of the isotopic composition and radioactive elements in living matter was now an important line of Vernadsky's work. One has to keep in mind that also this type of research was initiated almost 40 years before the main stream of biological sciences.

Back to Leningrad, Vernadsky tried to publish two books „*Living Matter*" and the German version of „*The Biosphere*". However, the books did not appear because of censorship. „*Living* Matter" was published only in 1940 under the title „*Biogeochemical Essays*".

In February 1934 the closest friend of Vernadsky the permanent secretary of the Academy of Science Sergej Oldenburg died. This death symbolised also the end of the Petersburg period of the Academy of Science. Soon after the Academy and Vernadsky's Biogeochemical laboratory moved to Moscow. One year later Vernadsky settled in Moscow.

Already in the beginning of the 30-s Vernadsky came to the idea of writing a book where his holistic view on the nature would be expressed both scientifically and „philosophically". By 1936 Vernadsky understood that his thoughts and scientific work could be expressed in two different books, one of them more „philosophical" and one mostly scientific. Thus Vernadsky began to work on his main works „*The Chemical Structure of the Earth's Biosphere and Its Environment*" (1965) and „*Scientific Thought as a Planetary Phenomenon*" (1991). Vernadsky completed these works although he did not write the final chapter of „*The Chemical Structure*". Both books were published only after Vernadsky's death. „*Scientific Thought*" was published first in 1977 in an abridged form. In 1936 Vernadsky writes in London, in the Library of the British Museum, an article „*On Logic of Natural Science*". In this article Vernadsky for the first time used the term „noosphere" (Aksenov, 1994, p. 453) which was coined by E. Le Roy in 1928.

In 1937 Vernadsky read a report „*On the Significance of Radiology for the Contemporary Geology*" (1939) at the 17th International Geological Congress.

One year later Otto Hahn, Lise Meitner and Fritz Strassman split the atom that made possible a chain reaction. In June 1940 Vernadsky received a letter from his son (George Vernadsky), who taught in Yale University (USA). George Vernadsky enclosed a *New York Times* clipping of May 5, 1940 that summarised research using the energy of chain reactions in the USA. V. Vernadsky immediately began to act. On July, 30 a Uranium Commission was created within the Academy of Science. Vernadsky asked his student V. Khlopin (1890-1950) to take chair of the Commission. Vernadsky and the physicist A. Ioffe were elected vice-chairmen of the Commission. The member of the Commission I. V. Kurchatov (1903-1960), who worked under Khlopin in the Radium Institute, began in the spring 1943 his work on the secret Soviet atomic weapon program.

After the war with Germany broke out (22 June, 1941) Vernadsky was evacuated to the health resort Borovoje in Kazakhstan. The two years in Borovoje were highly productive. Vernadsky wrote the important third issue of series „*Problems of Biogeochemistry*“ (1980) which he saw as his scientific will. He worked also on his main work „*The Chemical Structure...*“ where his basic claims, expressed first in „*The Biosphere*“ were revised and developed. Unfortunately, Vernadsky did not complete the final chapter of this book.

In August 1943 Vernadsky returned to Moscow and in 1944 published his last work „*A Few Words About the Noosphere*“, which he had written in Borovoje as well.

On 6 January 1945 Vernadsky died from cerebral haemorrhage at the age of 82.

1.2. *Intentions of this book*

At present there are about 1000 works published on the activity of Vernadsky. Practically all facets of his scientific and social activity are elucidated. Among others, there are three detailed scientific biographies of Vernadsky (Mochalov, 1982; Bailes, 1990, Aksenov, 1994). Some generalising theoretical works on Vernadsky's theoretical legacy were also written. As early as 1971 I. Mochalov defended his Doctor of Science (Habilitation) thesis *Scientific and Philosophical Fundaments of V.I. Vernadsky's Worldview*.

Nevertheless it cannot be said that Vernadsky's theoretical system is fully investigated, reconstructed, appreciated and critically analysed. Partially this can be explained by ideological pressure and censorship in the USSR, partially by the complexity and all-embracing kind of his scientific heritage. There are about 200 publications by Vernadsky in different languages directly connected with the themes biosphere and living matter. There are almost 700 articles and books of Vernadsky published in Russian, French, German, English, Czech and other languages. Besides, Vernadsky's views evidently evolved during his life and not all of his scientific projects were completed. E. Mayr (1982, p. 330) wrote about one of Vernadsky's scientific predecessors G. Buffon (1707-1788): „There are few thinkers who are as difficult to interprete correctly as Buffon“. One of these few thinkers was, without doubt, also Vladimir Ivanovich Vernadsky.

Despite of the difficulties pointed out above, in the present work I intend to show that Vernadsky has tried to create a theoretical system all parts of which are intimately interconnected. Each part of this system is relatively autonomous but its significance can only be fully understood in the context of the whole theoretical system. At the same time, I will subject this theoretical system to criticism and show some of its inconsistencies and contradictions. Vernadsky's theory of the biosphere will be compared with other important biosphere theories in order to define the place which Vernadsky's theory occupies between other global theories of 20th century. Also here methodological criticism of Vernadsky's theoretical system will be applied.

In this context some remarks should be made about the terms 'theoretical system', 'theory' and 'concept' as they are used in this book.

The term 'theory' will be used in its broadest sense. Theory is said to be a complex system of concepts which organises a certain class of phenomena (EPW, 1995; Liebscher, 1997). Theory is created for describing the essential characteristics and laws of the related field of knowledge. It is generally agreed that prediction (retrodiction) and explanation are central functions of a scientific theory (Liebscher, 1997). The important demand upon a theory is its non-contradictoriness (Widerspruchslosigkeit) (Weyl, 1966).

It is much more difficult to find a clear definition of the term 'concept'. Generally, the mental representation of any object can be defined as a concept: „Scientists form concepts and ideas to represent things in themselves and theorise by means of the resulting conceptual structures" (Tuomela, 1973, p. 8). The exact meaning of this term fluctuates and is assignable only in the context of a theory. The examples of concepts in biology are natural selection, population, altruism and so on. E. Mayr (1998) claims the importance of concepts in biology. Physical theories are usually based on laws, biological theories on concepts. The latter is correct not only for pure biological theories but generally for the related descriptive natural sciences including Earth sciences.

In the present work also the term 'theoretical system' is used, which is generally said to be a synonym of the term 'theory' (Liebscher, 1997). However, in the present work this term is used to assign the attempts of Vernadsky to create a conceptual structure embracing different sides of his theoretical activity. In short, 'theoretical system' means here a group of interconnected theories.

There is no general agreement about the status and structure of Vernadsky ideas. Vernadsky himself used the vague term *teaching* in relation to his main theoretical constructions. Ghilarov (1995) writes about Vernadsky's *concept* of the biosphere. Mirzoyan (1994) claims that Vernadsky created an original *theory* of living matter based on the modern achievements of the evolutionary theory, geochemistry, ecology and physics. According to Mirzoyan, Vernadsky's *theory* of living matter provides a foundation for his *teaching* of the biosphere. From my viewpoint, such classifications of Vernadsky's theoretical heritage are not convenient because of the following reasons: (a) The term 'teaching' is vague and we are not informed how the theory of living matter correlates with the 'teaching' of the biosphere and other conceptual structures of Vernadsky's theoretical system. (b) Vernadsky approached living matter geochemically and described the most important features of living matter by contrast to inert matter. The biosphere consists of living and inert „parts". Should we separate a 'theory of living matter' and a 'theory of inert matter' which forms the biosphere 'teaching'? (c) Some authors (Ghilarov, 1994; Zavarzin, 1997) reject Vernadsky's concept of living matter while accepting his biosphere theory in general.

For our purposes I propose the following conditional structuring of Vernadsky's theoretical heritage:

(1) The theory of the biosphere and its transition into the noosphere.
(2) The theory of space-time.
(3) The general philosophy (theory) of science.

In each theory Vernadsky creates a specific terminology, postulates laws and makes predictions (retrodictions) based on this theory. On this basis one may rather think of a theory of space-time instead a concept of space-time. At the same time, all these theories are intimately connected with each other and form a kind of megatheory or theoretical system approaching the processes of Earth based on the phenomena derived from geology, geochemistry, biogeochemistry, geophysics, biology and the history of science.

2. RECONSTRUCTION AND ANALYSIS OF THE THEORETICAL SYSTEM OF V. I. VERNADSKY

2.1. *Space and time in the works of Vernadsky*

2.1.1. *Introduction*

Vernadsky's theory of space-time is one of the least investigated sides of his theoretical system, although some works elucidating the diverse aspects of this problem were recently published (Aksenov, 1996; Eliseev, 1989; Galimov, 1989; Aronov R. & Terentjev, 1988). Bailes (1990, pp. 194-195) notes that the issue raised by Vernadsky has become important in the recent years.

The 'space-time' theme has a special place in the work of Vernadsky for several reasons. First, it seems to be extremely abstract and speculative. During his work with this topic, Vernadsky constantly went beyond the so-called method of 'empirical generalisation' he declared as a basic principle of scientific work. Second, the concept of space-time is directly connected with all basic principles of his theoretical system. Third, Vernadsky elaborates this theme taking into consideration several branches of knowledge - biogeochemistry, biology, physics, mathematics, philosophy and the history of science - and, thus, tries to approach the problem in a thoroughly interdisciplinary manner. Besides, this topic has a special interest because Vernadsky, during his work with it, constantly went beyond the so-called method of 'empirical generalisation' he declared as a basic principle of scientific work (Vernadsky, 1988, p. 439).

I will reconstruct and interpret Vernadsky's views on the space-time problem and define the place of this problem in his theoretical system (i.e. the connection between his treatment of the space-time problem and other fundamental ideas). I use the term 'reconstruction' here, because, first, I was forced elaborating this theme, to deal, partially, with disparate notations in Vernadsky's published works; and, second, Vernadsky investigated this subject mostly late in his life and so, unfortunately, did not have time to express his thoughts clearly and completely. Besides, one should bear in mind, that the scientific views of Vernadsky on the nature of space and time changed considerably towards the end of 1930's and the beginning of the 1940's. Therefore, the 'reconstruction' we attempt here is not only a hermeneutical but a logical reconstruction of Vernadsky's views as well.

2.1.2. *Space*

If we try to draw the logical portrait of the space-time problem from Vernadsky's viewpoint, then we better start with space because, with few exceptions, it is possible to propose that Vernadsky made the first and principal generalisations regarding space-time thinking about the nature of space, and then extrapolated the inferences to the nature of time.

The notion on which Vernadsky based his initial reasoning is 'the real space of the naturalist'. To the latter, he opposed the notion of 'the ideal space of geometry'. In his work *On the Border of Science. The Space of Natural Science and the Space of Philosophy and Mathematics* [which is dated 1927 by the editors], Vernadsky (1988, p. 210) offered the following definition:

> „The real space of the naturalist coincides with *the physical medium*,[1] in which the phenomena he deals with take place. It does when he expresses the phenomena geometrically. If a naturalist is talking about a real space of nature, he is talking about the geometrical *structure* of a physical medium. There is no ideal geometrical space for the naturalist. It would be real for him, if the observations showed that space is isotropic, homogeneous everywhere".

It is remarkable that Vernadsky still speaks in this connection that „there is no necessity to talk about a special geometrical space, which is connected with life"(Vernadsky, 1988, p. 212). He changed his mind later. This shows that in 1927 Vernadsky's concept of space-time was still not elaborated. But he already proposes the basic notion of the *real space of the naturalist,* on which he later builds his understanding of the problem.

The real space of the naturalist or *physical space* [2] [Helmholtz] (not to be confused with the space of physics) differs from ideal geometrical space, first, by having a structure, while geometrical space is a space of dimensions, not a space of structures (Vernadsky, 1988, p. 216; Vernadsky, 1993, p. 377). This proposition invites serious objections. Yet we have to take into consideration that Vernadsky sees the structure of real space as a complicated spatial organisation of natural bodies and processes which cannot be reduced to the ideal space of geometry but can be, to a certain extent, expressed geometrically. On the one hand, this reduction is impossible because of the insufficient depth of the geometrical analysis of real space (Vernadsky, 1988, p. 257), on the other hand, to the essential impossibility of completely reducing empirical reality to logico-mathematical schemes (Vernadsky, 1988, p. 216).

To reveal the essence of the notion of the structure of real (physical) space, from Vernadsky's viewpoint, is not so easy. He used different terms in works which were written at different times to characterise this phenomenon: a 'property of space', a 'geometrical structure of space', and a 'structure of space', and, ultimately, a 'state of space'. He did not give, as a rule, clear definitions of the differences between these terms. Therefore, I shall use the terminology preferred in the latest works of Vernadsky. This will help to some extent to achieve terminological consistency.

One of the central terms reflecting the structure of real space is *a state of space*: „Space has to be not only geometrically structured, but also must have different physical states" (Vernadsky, 1988, p. 324). The notion of a state of space Vernadsky credited to P. Curie who, in turn, borrowed it from L. Sohncke (1842-1897). Vernadsky was sure that noone among Curie's contemporaries had understood the real direction of Curie's ideas. He based this conclusion not only on the latest works of Curie but also quoted his personal talks with Madame M. Curie: „She thinks that it is in this notion (état de l'espace) contained the synthesis of his thought" (Vernadsky, 1965, p. 160). Vernadsky, nevertheless, was sure that Curie was not able to elaborate this idea because of his sudden death in 1906. Vernadsky saw his own work on space as a development of the ideas of Curie. By an irony of fate Vernadsky also did not have enough time to complete his work on the problems of space-time.

The notion of 'a state of space' makes it possible for Vernadsky to contrast his views to Kant's concept of space: „Geometry is not a manifestation of human reason a priori" (Vernadsky, 1988, p. 260). On the contrary, it is the manifestation of the states of space

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[1] The physical medium is treated by Vernadsky as a real medium (environment), rather than a medium of physics.

[2] Vernadsky often uses the terms *real space* and *physical space* interchangeably.

that can be examined by an investigation of solids. The significance of the solids, in this connection, is based on Vernadsky's idea that the other aggregate states of matter are not so 'receptive' to the different space states.

Space is discrete and deeply heterogeneous from the viewpoint of its states, because "every particle of matter is surrounded by its peculiar state of space" (Vernadsky, 1988, p. 291).

The state of space of a natural body is indicated by the investigation of its symmetry. The principle of symmetry is for Vernadsky one of the most fundamental principles of nature (Vernadsky, 1994, p. 297; 1988, p. 220). It can be sad that the principle of symmetry is for him a corner-stone of the problems to be discussed.

It is important to stress that the symmetry principle is fundamental also from the viewpoint of its place in the epistemological hierarchy that was built by Vernadsky. According to Vernadsky's terminology, this principle is *an empirical generalisation of the first kind.* This means that this empirical generalisation is made directly on the basis of the 'raw' facts (Vernadsky, 1988, p. 287). He writes (Vernadsky, 1988, p. 292):

> „Symmetry is not an abstract notion that is deductively derived, as the scientists often think. It is a result of empirical generalisation that has been worked out (first unconsciously) over the centuries. [...] Symmetry characterises the different *space*

Thus, the examination of the different properties of symmetry is an approach to the examination and the description of the different states of space.

For example, the state of a space that a scientist finds in homogeneous crystalline matter can be characterised as *an anisotropic state of space that is completely defined by the laws of Euclidean geometry.* The processes which take place in such a kind of space show the identity of leftness and rightness physically and geometrically.

The situation changes in the world of living organisms. Already L. Pasteur discovered dissymmetry in the crystals of tartaric acid. Organic compounds, which are typical for all kinds of living matter differ from compounds composing the inert (non-living) parts of the Earth. Pasteur called these two categories: „la nature vivante" and „la nature morte". There are always two enantiomorphs, which could theoretically exist. In the protoplasm of living matter one finds pure steric compounds. In the stereochemical equations of these compounds the atoms preferentially arrange in left-handed or right-handed isomers instead of a statistical distribution as could seem to follow from physical/chemical laws alone. Pasteur stated that the biochemical processes of living matter and their crystallisation products demonstrate the preferential synthesis and maintenance of left-turning or right-turning isomers. He called this phenomenon molecular „*dissymétrie*" and defined it as the demarcation line between living and abiotic natural products (Pasteur, 1922, p. 343).

Both the crystallisation processes and the biochemical processes in the living organisms demonstrate a non-identity of leftness and rightness. The organogenic bodies (for instance, petroleum) and the remains of organisms keep the same properties for geological periods of time. We can find, also, the same in the enantiomorphic phenomena. There is no proper *non-identity* of leftness and rightness in the inert matter (of abiotic origination), for example, in crystallography, although, the crystals are produced in left- and right- forms (Vernadsky, 1988, p. 298).

It is well-known in contemporary science that biological macromolecules diverge from other polymeric structures. Proteins are constructed only by *left-handed* amino acids, whereas DNA-RNA contain only *right-handed* sugars (Goldanskii & Semenov, 1992). If Vernadsky had known about these facts, he would doutlessly have added them to his arsenal of evidence.

The non-identity of right- and left- forms in the living nature Vernadsky called *the Pasteur dissymmetry.* Following Pasteur, he posed a question about the causes of that phenomenon. Why does an organism build its body of „left" or „right" isomers and consequently destroy the identity of leftness and rightness?

The identity of leftness and rightness is the geometrical property of the Euclidean space that was known already to Kant. The investigations of the crystallographers Fedorow and Schönflies approve that inference: rightness and leftness are identical in the crystalline space structures of abiogenic origin. Vernadsky concludes (1988, p. 270): „It follows that identity of leftness and rightness is the geometrical property of the three-dimensional Euclidean space". This proposal leads Vernadsky (1988, p. 271) to the next statement: „The lack of this identity and the cleancut prevalence of leftness in the material substratum of living matter and the prevalence of rightness in their functions points out that the space that is occupied by living matter could not correspond to the Euclidean space".

The concept of dissymmetry is a clue to Vernadsky's space-time theory. We shall see later that his understanding of dissymmetry is not identical with the phenomenology of Pasteur's dissymmetry.[3] Here it is important to stress that P. Curie extended the concept of dissymmetry and introduced the notion of state of space.

P. Curie claimed that if some effects manifest a dissymmetry, then the same dissymmetry must be observable in the causes of these effects, although the contrast does not hold. The effects can be more symmetric than the causes (Curie, 1908). Curie connected this principle with the idea of a „state of space" (état de l'espace) and, thus, postulated a *dynamic* (maybe it is even possible to say 'hereditary') character of dissymmetry.

Vernadsky proposed a principle, which he called *the Curie (or Pasteur-Curie, or dissymmetry) principle*: „Dissymmetrical effects (phenomena) can be brought about only by a dissymmetrical cause". He realised that, if space is a kind of intelligible reality, then the causes and their effects must find themselves in the same state of space, i.e. they must be embraced by a certain state of space (Vernadsky, 1965, p.182). As E. Eliseev (1989, p. 196) remarked later, the addition made by Vernadsky is so important that the latter principle should be called *the Curie-Vernadsky principle.* This is also correct, Vernadsky's dissymmetry is only a special case of Curie's asymmetry.

In the theoretical world of Vernadsky the principle of symmetry is refracted not only by the prism of dissymmetry, but also by the character of symmetry in living matter. It manifests itself, first of all, in the fact that the kinds of symmetry in inert matter is restricted. In the living world one can observe bioobjects with axes of symmetry of 5, 7, 8, 9 etc. orders not observed among the crystals. Already first crystallographers

[3] There is no terminological clarity in the use of the terms *dissymmetry* and *asymmetry*. J. Urmantsev defines asymmetry as an opposition to symmetry and separates it from both dissymmetry and antisymmetry (Urmantsev, 1974). Alpatov holds that the term asymmetry occurred in this context because Pasteur's term *dissymétrie* was translated in English, Russian and German as asymmetry (Alpatov, 1957, p. 21). This conjecture seems to be the justified one, because, for instance, Japp (1898) and D'Arcy Thompson (1961) use *asymmetry* as it were Pasteur's *dissymmetry*. Moreover there are two spellings of this term, namely, as *dis*-symmetry and *dys*-symmetry which has different shades of meaning (*Dictionaire Alphabétique et Analogique de la Langue Française*). In the present work we use the term *dissymmetry* to stress the special meaning Vernadsky attached to this notion. We use here the prefix *dis*- not *dys*- in order to follow the spelling of Pasteur.

justifiably pointed out that there are no regular dodecahedrons among the natural crystals (Vernadsky, 1988, p. 262). At the same time, it is possible to reveal the axes of the fifth and sixth order in living organisms (Vernadsky, 1988, p. 264). The up-to-date level of biological science makes it possible to describe samples with even much higher structural symmetry than Vernadsky mentioned. Contemporary investigations show that we can find in living matter not only dodecahedrons (*Circorherma dodecahedra*) but also macrobioobjects with symmetry axes of 5, 7, 8, 9 etc. orders. Orders, which are not realised in the mineral world. The contemporary researcher of symmetry J. Urmantsev holds that the macrolevel of symmetry also demonstrates the correctness of Vernadsky's thesis of a specific character of the biological space (Urmantsev, 1974, p. 219).

These phenomena - the orders of the structural symmetry on the macrolevel and dissymmetry on microlevel - lead Vernadsky to say that there is a clear-cut difference, without transitions and exceptions, between the symmetry of the inert bodies of the biosphere and the spatial-temporal organisation of living matter (Vernadsky, 1988, p. 284).

Moreover, Vernadsky points out other important features that characterise the spatial peculiarities of living matter: dispersiveness, stability, and curvilinearity.

Dispersiveness manifests itself in the sharp separateness of a living organism from its environment. An organism is a constantly moving geometrical body sharply separated from its environment. The only connection between the environment and the organism is a biogenic (biologically controlled) migration of atoms.

Stability finds expression in the stability of a form in which the living being exists. This form, as a matter of fact, is being constantly re-created in a dynamic equilibrium. One can point out kinds of organisms the forms of which have been stable for hundreds of millions of years.

Curvilinearity. The scientist should also take into consideration that an organism is always separated from its environment by *curved surfaces*. This characteristic was termed by Vernadsky curvilinearity. In this connection, D'Arcy Thompson (1961) stressed that in mechanical (inert) structures curvature (*curvilinearity*) is found in flexible structures as the result of bending. Living natural bodies „have not been bent into their peculiar curvature, they have grown into it" (Thompson, 1961, p. 179).

All these peculiarities of the spatial organisation of living matter - the peculiar properties of symmetry on the macrolevel, the dissymmetry of Pasteur, stability, curvilinearity of surfaces and dispersiveness - make it possible to propose that the *space* of living natural bodies differs principally from the space of their inert environments. He assumes that „the bodies of living organisms are determined by a geometrical state of the space they occupy, other than the Euclidean space of the inert natural bodies of the biosphere" (Vernadsky, 1988, p. 273). Another concept of space thus emerges.

The inference is important for Vernadsky not only as one of the basic principles of his scientific Weltanschauung, but also as a methodological consideration. It enables the definition of a more precise boundary between *bioinert bodies* and living organisms: „A living organism, seen as a whole, although a bioinert natural body by its consistency, differs sharply from a genuine bioinert body primarily because of the space that is occupied by them" (Vernadsky, 1991, p.168).

In 1938 Vernadsky thought that the geometrical properties of the state of space of living matter corresponds to Riemann's space. Later in the unfinished article „*About the Geological Significance of Symmetry*" (dated 1941-1942), he rejected this idea (Vernadsky, 1988, p. 284-285). This was partially because living matter has not only spatial but also temporal peculiarities, which are not found in inert matter.

2.1.3. *Time*

Analysing the problem of time, Vernadsky, first of all, appeals to its irreversibility, i.e. to the problem of the direction of time: „If we start to analyse the notion of time and try to understand the World from the viewpoint of the time problem, it is apparent: whether a process in time goes as easily forward as backward, i.e. whether a process is reversible or irreversible" (Vernadsky, 1988, p. 223).

He holds that the processes giving rise to the inert natural bodies of the biosphere are reversible, whereas the processes producing the living natural bodies are evidently and fundamentally irreversible (e.g., fission). This is the basic thesis of Vernadsky. The first part of this thesis hints at the claims of some contemporary scientists and philosophers of science that, taking into account only the fundamental physical laws, there would be no intrinsic difference between the future and the past (Savitt, 1996, pp. 335-336). Not only the laws of classical dynamics and electromagnetism, as well as of quantum mechanics, are all expressed by time-symmetrical differential equations, but also, according to P. Horwich, „even the notoriously irreversible phenomena of thermodynamics - processes of entropy increase which are typically associated with time's arrow - can be reconciled ... with the isotropy of time" (Horwich, 1987, p. 55).

The question that is posed by Vernadsky may be formulated as follows: does the irreversibility which is apparently an essential attribute of *biological time* also apply to the time of inert matter? We can consider some more questions in connection with this problem. If the laws of physics are symmetrical in relation to time but the laws of biology are not, then do we have a basis to declare that there are two parallel times in the universe? If this question nevertheless in consideration of the wholeness of the universe sounds absurd, then what is the cause of this apparent double-temporality?

We can consider one more problem in this connection. As H. Frauenfelder (1987, p. 221-229) showed, contemporary science is close to answering the question of Schrödinger [1944] (1992, p. 3): „How can the events *in space and time* which take place within the spatial boundary of a living organism be accounted for by physics and chemistry?" If Frauenfelder is right, we can, from the viewpoint of physics and chemistry, examine the time-space properties of living matter. But, if we accept the hypothesis of Vernadsky, the question occurs: how is it possible to describe the temporal phenomena of living matter, which are dissymmetrical, by means of the laws of physics if they are insensitive to the directionality of time?

In an attempt to answer these questions with the help of Vernadsky's texts, we find different ways to escape the problem of 'double-temporality'.[4]

Vernadsky's epistemological remarks can be referred to the first way of escaping this difficulty. According to Vernadsky (1988, p. 231), we can understand the phenomena of life better than the phenomena of the abiotic physical world: "Being a part of life, scientific thought has a great cognitive power in this field. It is not as powerful in examining the other manifestations of the universe, remote from the organisms". To clarify this thesis we should keep in mind two other points. Vernadsky held scientific thought to be a manifestation of nature, a function of the biosphere (see Ch. 2.2). This assumption connects his numerous remarks about the specific character of the biological sciences. The life sciences are essentially reflective in character because the human being is both the object and the subject of investigation at the same time.

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[4] It should be remarked that Vernadsky never posed the problem of double-temporality as we do. The problem is following his inferences.

The second important point derives from the first. Since the scientific thought is a function of the biosphere, it is adapted to the really existing conditions of the biosphere: „The logical laws of the natural sciences are different in the different geological layers of the Earth" (Vernadsky, 1988, p.280). The cognitive apparatus of human being is adopted to the existence in the biosphere. In this respect the views of Vernadsky can be compared with the ideas of K. Lorenz (1903-1989) - one of the forerunners of the contemporary evolutionary epistemology - who claimed (1941) that the laws of "pure reason", including the categories of space and time, are based on the complex mechanical structures of central nervous system developed in the course of evolution. However, Vernadsky went further, and stated that the laws of physics do not penetrate reality as deeply as laws of descriptive natural sciences (e.g., the biospheric sciences). For example, the laws of physics do not explain the unidirectionality of time. This thought could be expressed in the following thesis: statistical thermodynamics cannot compete with the empirical generalisations of descriptive sciences because of its abstract and symbolic character (as a minimum it implies the use of mathematical symbols). At the same time, the empirical generalisation of the life sciences are almost direct representations of the concreteness of the world (Vernadsky, 1994, pp. 325-326).

If we move in this direction, we do solve the 'double-temporality' problem, but we lose the subject of our discussion, i.e. the real peculiarity of biological time: double-temporality turns out to be an epistemological problem.

It is also possible to try an approach to the problem of co-existing 'biological' and 'physical' times by showing common properties of time in living and inert matter. This is the direction of the relatively early works of Vernadsky. We solve the 'double-temporality' problem by showing that there is no double-temporality in an observable world, although the irreversibility of time of the physical world is not so evident as in the world of life phenomena. We could do it, following Vernadsky, proceeding from the principle: „Time is one of the essential manifestations of matter, the inseparable content of it" (Vernadsky, 1988, p. 229).

He points out some of the features of living and non-living matter which could be considered as similar. If we approach the problem geochemically, the atoms show a property that Vernadsky termed *transitoriness* [бренность]. Every radioactive atom has a certain time of existence and is connected genetically, in its origin, with the other atoms. Vernadsky makes two empirical generalisations on this basis: „Every kind of atom has its place. This is the basic empirical generalisation. The other one is this: The process of the regular transitoriness of the atoms goes inevitably and irrepressibly" (Vernadsky, 1988, p. 230). The inference is that this process is irreversible. It is to be expressed by *polar vectors* and characterised by a certain rhythm (Vernadsky, 1988, p. 230-231). At the same time, we know that the stable isotopes can exist infinitely if they are not influenced by external factors.

Biological time is also irreversible and can be expressed by a polar vector. Biological time is expressed as:

- a time of an individual being;
- a time of changing of the generations without changing of the life forms;
- a time of changing of the generations simultaneously with changing of the life forms (evolutionary time).

Biological objects demonstrate the same rhythmical and polar properties. There are also the *indivisibles* (individuals) of the unicellular biological organisms that have no limit to their existence as well as the stable isotopes (as long as they are not influenced by external factors).

If we go this way, we find that the properties of time in living and inert matter are similar. Vernadsky generalises these cycle of ideas in the work „*The Study of Phenomena of Life and Modern Physics*“ (1931), which was inspired by Eddington's „*The Nature of the Physical World*“ (1928). Vernadsky adopted his principal methodological approach - to connect the irreversibility of time with certain natural processes - and a while was determined to find a 'time arrow' in the physical world. That is the second way to solve the double-temporality problem but, at the same time, we also (as in the first case) lose the necessity of talking about a fundamental peculiarity of biological time. Besides, the attempts to show the existence of nomological (Mehlberg, 1961) temporal anisotropy in the physical world did not seem successful back then, and the question remains moot (Savitt, 1996, pp. 347-370). Vernadsky seems to have later discarded this approach, which he had outlined in his works at the beginning of the 30-s.

Do we still see a chance to define the peculiarity of biological time?

In his latest works Vernadsky tries to do it by means of the four basic notions: natural body, duration, symmetry and entropy. It is not the way to solve the double-temporality problem completely, but it is the way to take the problem out of the biosphere and consequently out of the domain of phenomena Vernadsky mainly deals with. The hypothetical methodological ground of this approach could be interpreted in the following way: assume that in the frame of the biosphere there are some fundamentally different kinds of natural bodies and fundamentally different kinds of processes in which they participate. Then reduce the 'times' to the properties of these natural bodies. Doing so, we could define the peculiarities of the different 'times'. The ontological consequences of this step will be for now ignored.

In this paragraph I treat the first three notions (natural body, entropy, duration) leaving the problem of symmetry to be discussed in the next one.

The notion of *a natural body* is very important to the understanding of Vernadsky's theory. He defines natural body as every natural material-energetic phenomenon separated in space and time from other natural bodies (Vernadsky, 1965, p. 161). Being applied to the problem of biological time this notion allows to describe temporal properties of the separate natural bodies of the biosphere (e.g., living organisms and minerals of the abiotic origin) ignoring the ontological consequences of these generalisations.

Another important notion which appears in this context is *duration*. The term is derived from the term 'durée' of H. Bergson (1859-1941). Vernadsky knew the work of Bergson very well and doutlessly was influenced by it, although he naturally was not a Bergsonian. Despite the methodological gulf between their approaches, it is easy to understand the interest of the scientist to the philosopher. There are some common points in their way of thinking.

I can mention some of them.[5]

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[5] The concurrence of theirs (Vernadsky's and Bergson's) views is also interesting, because Bergson was a close friend of E. Le Roy, one of the creators of the „*noosphere*“ concept. Le Roy was a hearer of Vernadsky's lectures at Collège de France (1922-1926).

- The assertion of Bergson that geometry can be applied only to solids (Bergson, 1969, p. 161-162) is similar to that of Vernadsky that space shows its properties through the solids (crystals).
- The dualism of Bergson, a division of the world in two parts: living and non-living, is, without any doubt, one of the points of contact. It is even possible to show the terminological coincidence of their two theories. Bergson, for example, uses a term 'la matèrie brute' to define non-living matter (Bergson, 1969, p.154). This term is similar to the Russian term 'косная материя', which can be translated in English as inert (sluggish, crude) matter.
- The idea of creative evolution is close to Vernadsky's views, because it compounds the idea of directionality with a kind of indeterminism and because of the creative character of evolution. Vernadsky (1988, p. 332) writes in the work „*On Living (Biological) Time*" (1931): „Time goes in one direction, the direction of the outburst of life and the creative evolution. The process is irreversible therefore this outburst and this evolution is a fundamental requirement for the existence of the universe. Time is a manifestation and a creation of this world process".

It is possible to point also to some other coincidences. But, first of all, we are interested in the notion of *duration* which has played an important part in the development of Vernadsky's thinking.

Bergson (1969, p. 202) understands *durée* (duration) as time which is an essential of life in contrast to the quantitative time of mathematics which is only a collection of outward moments. In duration the unpredictability of life and the novelty of the present is revealed. In line with this, thanks to duration life assumes the characteristic of freedom.

Vernadsky analyses briefly the evolution of the term *duration* to stress the aspects of this notion which are interesting to him. J. Locke (1632-1704) introduced the English version of the term ('duration') in 1693 when he found a difference between the time of Newtonian physics and mental time. A duration reflects, according to Locke, a time of the thinking being. The Newtonian time was a result of theoretical construction. The time of Locke was a result of observation. This is important for Vernadsky, because Bergson also built his theory on the basis of observation but on much more considerable empirical data. He treats duration also more broadly than Locke and beyond the frames of psychological time. The latter forced him to abandon the absolute time of Newton. If the time of Locke can co-exist with Newton's time, the time of Bergson is certainly incompatible with it: „Bergson's time is a real time that manifests itself during the creative evolution of life. It is manifested in scientific facts and phenomena and hence can be perceived both in science and in philosophy" (Vernadsky, 1988, p. 332).

The time of Bergson, in short, is a heterogeneous and irreversible time. Geological history, the evolution of species and humanity turn out to be irreversible.

Vernadsky had held in 1931 that, according to new scientific data, that the notion of duration can be applied also to physical time (Vernadsky, 1988, p. 334). He later, by the end of 30s, abandoned this proposal.

Vernadsky derived from his biogeochemical experience, that the processes producing the inert natural bodies would show cyclic, reversible, undirected character in the absence of living matter: „The same minerals and rocks came into being since the Cryptozoic until nowadays" (Vernadsky, 1965, p. 325). The processes in which living natural bodies are involved (aging, changing of generations, evolution) show, in the contrary, their evident irreversibility. Thus, in the frames of the biosphere we can interpret the trajectories of processes in which inert natural bodies are involved as reversible and those in which living natural bodies are involved as *irreversible* (Vernadsky, 1991, p. 176). At the same time we should bear in mind the restrictions appended to this claim by the notion of natural body and the assumption that a human being can think without serious corrections only within the biosphere.

Substantial irreversibility turns out to be proper only to living matter, because evolution (an irreversible process) takes place only among the living natural bodies of the Earth (Vernadsky, 1988, pp. 30, 175, 181, 286). Accordingly, Vernadsky should have changed his mind about Bergson's duration and understood it as proper to living matter in the biosphere.

Apparently, life as an embodiment of the vital outburst cannot have something in common with increasing entropy. In the notes written 1941-1942 Vernadsky writes: „Time, being expressed by a polar vector in physical-chemical and biological processes in living matter, is irreversible; it does not go back. That shows that entropy will take no place in the material medium of living matter" (Vernadsky, 1988, p. 274). This thesis should be commented upon, although Vernadsky by himself did not give any clear explanations of what he meant. It was usual in the time of Vernadsky to associate the 'time arrow' with the increase of entropy. This view was initiated by the discovery of Bolzman's *H*-theorem (1872) and represented in detail in the already mentioned book of Eddington *„The Nature of the Physical World"*. Nevertheless, Vernadsky connects the irreversibility of time in living matter with the opposite idea, that living natural bodies escape entropy. The latter was (approximately at the same time) remarked also by Schroedinger (1992, p. 71), who noted that living organism 'feeds on negative entropy'. Vernadsky, plausibly, held that this 'escaping entropy' and an increasing 'negative entropy' can be connected with basic biological processes, such as growth, fission, multiplication, mutation, and evolution which seem to be so evidently and fundamentally irreversible. Besides, Vernadsky, as biogeochemist, could see that the evolution of the biosphere is a movement to more perfect orderliness and stability and, hence, not only the evolution of living matter, but the evolution of the whole biosphere is an irreversible process. The cause of this irreversibility is the presence of living matter in the biosphere.

Summarising and coming back to the problem of double-temporality I can say that Vernadsky in his latest works understands the problem of irreversibility of time as follows: irreversibility of time manifests itself in living matter much more clearly and deeply then in inert matter, although irreversibility can be observed in the inert world as well (Vernadsky, 1965, p. 192). This means that there is a crucial difference between the two kinds of irreversibility. One could say that the irreversibility of time of living natural bodies in the biosphere is nomologically necessary, whereas the irreversibility of time of inert processes appears to be nomologically contingent.[6] This difference follows from the actual difference between the processes taking place in the two kinds of matter rather than from epistemological choices.

It was already stressed that Vernadsky in his late works tried to restrict his claims to the frame of the biosphere. If one would, nevertheless, try to interpret his claims from the more general perspective, one could arrive at the conclusion that the whole Universe is temporally dissymmetrical due to the presence of life. This extreme view is

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[6] This kind of irreversibility (anisotropy of time) can be treated in the terms of H. Mehlberg (1961) as *nomological* because of the use of the concept of law of nature it involves. In our case irreversibility seems to be tied up with the fundamental laws of biology.

represented by the Vernadsky researcher G. Aksenov (1996) who argues that, according to Vernadsky, living matter is the cause of temporal dissymmetry of the Universe. It would mean that the 'time arrow' is determined by the process of life.

2.1.3. *Space-time*

As we already stated Vernadsky's theory of space and time did not emerge until the last years of his life: the end of the late 1930s and early 40s. Thus, for example, in 1938 he concluded: „The biosphere is the Earth's layer in which living natural bodies are dispersed among the inert natural bodies. The state of space of the inert body is defined by Euclidean, three-dimensional geometry. The state of space of a living natural body is defined by Riemannean geometry. Hence, the biosphere looks as if numerous Riemannean spaces were embedded in Euclidean space" (Vernadsky, 1988, p. 274).

In the early 40s Vernadsky gives up this idea. He tries to break through the frames of physical-mathematical schemes to the space-time of descriptive sciences. For this reason he develops the notion of '*the real space of the naturalist*' to the logical limits. Simultaneously, based on Bergson's ideas, his understanding of time develops in the same direction, indicated by the real data of the descriptive natural sciences. He, among others, greatly appreciates Bergson because the latter realised that the real processes which take place in living matter cannot be fully expressed by mathematical (physical) schemes of time. The time that Vernadsky tries to describe could be also called '*the real time of the naturalist*'. Elaborating these notions, he realises that they can be developed separately only to a certain extent and already in the work '*Time*' [1930-31] he stipulates the properties of the space of living matter by the properties of biological time (Vernadsky, 1988, p. 224). Later he also coins the term '*real space-time*' (Vernadsky, 1965, p. 192). Vernadsky contrasts his understanding of space-time to the space-time concepts in physics and mathematics. There are no mathematical models exactly corresponding to the space-time constructed by *the real time* and *the real space of the naturalist*: „It is not the space-time [*continuum*] that includes time as the fourth dimension of space, the space of mathematics (Palagij, Minkowski) or the space of physics and astrophysics (Einstein)" (Vernadsky, 1988, p. 285).

Nevertheless there is a principle that makes scientifically possible the description of the state of this space-time. It is the principle of symmetry. Both time and space can be interpreted through the prism of this principle. Vernadsky determined the space of living matter as dissymmetrical. The *space-time* of living matter could be also called *dissymmetrical*, because *Vernadsky connects the irreversibility of time with the dissymmetry of space* (Vernadsky, 1988, pp. 224, 284-285; Aksenov, 1996). From the viewpoint the notions that characterise, for example, fundamental spatial properties of a natural body (e.g. symmetry) would reflect the properties of the space itself and therefore the time, because, thanks to the inseparability of space and time, the characteristics of space and time must be mutually transformable. Then, the question 'Why is the time of living matter irreversible?', can be answered 'Because the space of living matter is dissymmetric'.

The real space-time of living matter is described by polar vectors; it is „enantiomorphic"; leftness and rightness are not identical in it. In space-time of the inert environment there is no manifestation of actual non-identity of leftness and rightness; it obeys the laws of symmetry in this domain; the time of this space-time shows nomological isotropy; it is symmetric. Hence, there is an impassable boundary between the states of space and time of living and inert natural bodies of the biosphere.

Dissymmetry distinguishes, and as it were, isolates living matter from the inert environment. The only connection between them is the biogenic (biologically catalysed) flow of atoms.

The dissymmetry of space-time is one of the basic features indicating the dynamic characteristics of living natural bodies. We could, for example, ask ourselves, whether the leaves of a lime-tree dried for a herbarium are living natural bodies? The following could be an approximate answer: although the pressed leaves manifest static space dissymmetry on the micro- and macrolevel they demonstrate no dynamic dissymmetry. Dissymmetry is a constant choice of the organism, a permanent process in the scale of the whole biosphere. The bilateral biocontrolled flow of atoms does not take place in this case because there is no dynamically filled boundary between the space-time of the pressed leaves and the space-time of the environment: „Death is the destruction of the space-time of the organism" (Vernadsky, 1988, p. 285).

2.1.4. *Comments*

The basic principles of Vernadsky's space-time theory can be deduced, to a certain extent, from the notions of the real space and the real time of the naturalist. His concept can be schematised in the following limited logical sequence: *real space - space-time - dissymmetry of life*. The second variant has equal validity: *real time - space-time - dissymmetry of life*. Both variants are logically symmetrical, because the notion of *real space* would inevitably lead us to the notion of *real time* and vice versa. Both notions lead us to the *real space-time*, which can be contrasted to the space-time of physics (Einstein) and mathematics (Vernadsky, 1965, p. 192). At the same time, either of the variants lead, if we accept the theoretical premises, to the notion of dissymmetry. It means approximately the following: if we, for example, call the time *real* and imply (under this reality) *the property of a certain process or a natural body*, we would very soon discover that there is no time in nature separate from space and all natural processes occur in space and time. Vernadsky stresses many times that naturalists implied while philosophers logically perceived space-time, long before the relativity theory. To prove the independence of the space-time concept from the dominance of physics, he undertakes a scientific-historical investigation and concludes: „The separation of space and time is not supported by a single scientific fact" (Vernadsky, 1988, p. 321). Further, if we ask ourselves about the difference of the diverse 'times', bearing in mind '*the reality*' of time, the answer would be apparent: the properties of the processes would be considered as the properties of these times. We could do the same thing manipulating the notion of space. Then, appealing also to *the reality of space*, we could transmit the properties of space to the properties of time reversibly. Since the principle of symmetry is one of the main principles of the Universe, and dissymmetry is one of the inexplicable and impressive properties of living systems, it is reasonable to construct the disparate pair *symmetry - dissymmetry* by gathering the proper empirical data. If we assume that our space-time is, also, the property of a process, it would turn out that space-time exists in two absolutely different forms: symmetrical and dissymmetrical. Hence, there are two sharply different space-times according to their properties in the Universe.

Further, if we accept that space-time is the inherent property of our world, we would have two worlds in one. The latter contradicts absolutely the scientific Weltanschauung of Vernadsky (1991, p.157). We can propose that in order to escape this paradox he introduces in his latest works two theoretical assumptions. First, he holds that all of the scientific descriptional systems (for example, all from the correct geometries) are of equal standing (Vernadsky, 1991, p. 70). The second assumption is that there are three realities in the field of our scientific observation: cosmic, biospheric and the reality of the microworld. This concept was in modern science held, for example, by Krumbein (1990) who speaks about macroscopic, mesoscopic and microscopic areas (Bereich) of the Universe. According to this, one can talk about three space-times (Vernadsky, 1991, pp. 46, 68). So space-time becomes the 'vertical' dimension if we regard the opposition living-inert as a 'horizontal' dimension.

This is one of the possible ways to restrict the inferences from the frames of the biosphere and escape the ontological consequences of his *empirical generalisations* on the nature of space-time. For, even if we assume, following the „early" works of Vernadsky (1931), that the space-time of the whole Universe is assymmetric, it does not help us to solve the problem of relations between dissymmetry and symmetry of this asymmetrical World. That is why, in all probability, Vernadsky in his late generalising works talks about the space-time phenomenon mainly as it is represented in the biosphere.

Such concern for detail was, also, in accordance with his epistemological and methodological principles.

Thus he inevitably arrives at the notion of a *natural body*. The latter combines two properties, being a real object of investigation and a logical category at the same time. This allows Vernadsky (1965, p. 17) to restrict logically the scale of the problems discussed by the limits of a natural body. The introduction of the notion of a natural body allows the following: a) to restrict the scale of the discussed problems by to the limits of the biosphere; b) to elaborate concepts of living and inert natural bodies which are of great importance for his theoretical system; c) to approach space-time as a natural body; d) to bind the properties of space-time with the properties of any given natural body. Vernadsky (1991, p. 155) wrote in this context, that „scientific thought and scientific work *proved* the necessity of recognising space-time as a real, all-embracing and unified natural body, beyond which scientific thought (which deals with reality) cannot, for the time being, exist (perhaps it follows from the nature of things)". Space-time as a natural body turns out to be an object and a fundamental category of the descriptive natural sciences.

Thus, the whole theoretical construction is based on the thesis of the *reality* of the real space and time of the naturalist. The fundamental question it raises is the following: to what extent do the properties of the natural processes (bodies) reflect the properties of space-time?

In order to answer this question in relation to space we should come back to the notion of *state of space*. Vernadsky uses the term 'state of space', plausibly, in two meanings. The first meaning can be called *general meaning* and corresponds to the general „geometrical situation". As pointed out by Eliseev (1989), the state of space of a natural body is reflected by its symmetry. In this sense, there are so many states of space as natural bodies exist (Vernadsky, 1965, p. 174). In the narrow sense, a 'state of space' corresponding to a certain natural body will be determined by the *basic principle of symmetry*. This principle declares that the state of space of a natural body will be determined by the minimum symmetry in its structure (Vernadsky, 1988, p. 379). Dissymmetry of life corresponds, probably, to the special case of symmetry breaking, because it is completely out of the traditional laws of symmetry of inert bodies. Taking into account the narrow sense of the term 'state of space' and the special meaning of dissymmetry of Pasteur, we can understand why the state of space of a living natural body in general will be characterised as dissymmetrical, although some elements of its structure are symmetrical and asymmetrical.

In relation to time the following should be said. It is known that Vernadsky was influenced by the Eddington's theory of time, but he accepted the ideas of Eddigton in a very peculiar way: Vernadsky was impressed not by the thermodynamic explanations of the 'time arrow', but by the idea of associating of the properties of time (and accordingly of space) with the properties of a fundamental natural process. For Vernadsky as the first biogeochemist it was clear, that the processes, which take place in the inert 'part' of our planet, in the absence of life, are completely reversible. On the contrary, irreversibility is intrinsic only in the phenomena and processes of living natural bodies. What Vernadsky extracted from Eddington's work is similar to what A. Gruenbaum calls *the Leibniz principle*, but in an altered form. Gruenbaum (1974, p. 197) phrases the Leibniz principle as follows: „...If two states of the world have precisely the same attributes, then we are not confronted by distinct states at different times but merely by two different names for the same state at one time". In Vernadsky's case we could replace 'world' by 'biosphere' and 'two states with the same attributes' by 'imaginary inert geochemical processes in absence of living matter' or, under certain circumstances, by 'two inert natural bodies'. If somewhat imaginary inert geochemical processes of the geosphere in absence of living matter have precisely the same attributes, then we are not confronted with distinct inert natural processes but with two different observations of the same processes in a reversible, undirected time. The same can be said about separate natural bodies: time of the inert natural body is reversible, because „all physico-chemical processes of inert natural bodies are reversible" (Vernadsky, 1939[1]). If we apply the same approach to the time of living natural bodies, we arrive necessarily at the concept of an irreversible time.

A similar line of thought can also be applied to the analysis of spatial properties. From the viewpoint of Vernadsky, the notions that characterise, for example, the fundamental spatial properties of a natural body (e.g. symmetry) would reflect the properties of the space itself and therefore of time, because, thanks to the inseparability of space and time, the characteristics of space and time must be mutually transformable. Then, the answer to the question 'Why is the time of living matter directed and irreversible?', can be formulated 'Because the space of living matter is polar'.

2.1.5. *The place of the space-time theory in the theoretical system of V.I. Vernadsky*

A space-time construct can be treated more or less as substantial, as dynamic, or as relational. We have to answer in this connection the question: why does Vernadsky choose specifically final point of view in answering the question about 'the relationship' between space-time and matter?

His position is determined by the whole logic of his scientific evolution and is closely connected with the all-important principles of his theoretical system. It is not difficult to demonstrate this point because Vernadsky many times referred to it in his works of the 30s and 40s. This was a time period, in which his most significant theoretical books „*Scientific Thought as a Planetary Phenomenon*" (1938) and „*The Chemical Structure of the Biosphere of the Earth and of its Environment*" (1940-1944) were written.

The space-time theory of Vernadsky is required to prove the thesis of the cardinal difference between living and inert matter and, hence, the indeducibility of the biological processes from the separate set of physical-chemical laws. The problem of the cardinal difference between living and inert matter is, in its turn, connected with all theoretically important claims of Vernadsky's theory of the biosphere: (i) the first, second and third biogeochemical principles, (ii) the Redi principle, (iii) the concept of the evolution of the biosphere, (iv) the classification of substances in the biosphere, and (v) the noosphere concept.

The hereditary character of the dissymmetry of living matter is explained stepwise by *the Curie-Vernadsky (dissymmetry) principle*: A dissymmetrical effect can be brought about only by a dissymmetrical cause.[7] Hence, talking about both 'a cause' and 'an effect', we are talking about dissymmetrical space-time as a cause and an effect in itself.

We can also say that the dissymmetry principle is correct if the transition from a dissymmetrical space-time to a symmetrical one is impossible without the loss of its own identity (substantial characteristic). However, such a transition from a dissymmetrical state of space-time into a space-time of the inert environment can be, according to Vernadsky, constantly observed. It is death. The transition from a symmetrical state of space-time to a dissymmetrical state of space-time is impossible.

In the Vernadsky's theoretical system, the Pasteur-Curie principle brings about, with a logical inevitability, what Vernadsky calls *the Redi Principle*: *Omne vivum e vivo* [all life from life][8]. The Redi principle (F. Redi, 1626-1697), in turn, proves the dissymmetry principle: we observe multiplication, hence, we observe the reproduction of dissymmetrical space-time.[9] In other words, multiplication is required by this principle. If there were no impassable boundaries between living and non-living matter, we could observe abiogenesis, i.e. the origination of living matter from non-living matter as a trivial process in the biosphere. The irreversibility of the biological processes follows, also, the dissymmetry principle, because the space-time of living matter, being dissymmetrical, is described by polar vectors.

The Curie-Vernadsky principle also requires the necessity of the spreading of life which is accompanied by the production of free energy which Vernadsky calls '*biogeochemical energy*' and by biologically controlled migration of atoms (Vernadsky, 1991, p. 171). The energetic-spatial-temporal difference between living and inert matter causes the biogenic flow of atoms which is the very subject of biogeochemistry and is described by Vernadsky's biogeochemical principles. Thus, the biogeochemical principles (see: 2.3.6.) describing the increase of biogeochemical energy in the biosphere (Krumbein & Lapo, 1996, p. 123) are also connected with his space-time theory.

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[7] Vernadsky knew that a version of this principle was also formulated by F. R. Japp (Vernadsky, 1965, p. 198) in the following form: „Only asymmetry can beget asymmetry" (Japp, 1898, p. 458). D'Arcy Thompson, in his fundamental work about symmetry in nature, remarked concerning this proposition of Japp: „In these last words (which, so far as chemist and biologist are concerned, we may acknowledge to be true) lies the crux of the difficulty" (Thompson, 1961, p. 138). Nevertheless, Vernadsky called this principle - the principle of Pasteur - Curie. This is, plausible, because of the widely-spread belief in the vitalistic views of Japp.

[8] Vernadsky made a mistake. The Redi principle sounds "ex ovo omnia" (all life from egg) (Jahn, 1998, p. 228). Vernadsky used a version of this principle coined by Pasteur.

[9] The idea of an essential connection between self-replication and dissymmetry is, in a certain sense, self-sufficient and can be included in opposing theoretical systems (see 3.1.). For example, V. Goldanskii and his colleagues go the same way working out the theory of abiogenesis: „The coexistence of two typical properties of living systems that are unique from the standpoint of physics, namely, self-replication and homochirality, and only these two properties, already predetermines the path of pre-biological evolution" (Goldanskii & Semenov, 1992).

In the theoretical world of Vernadsky, the peculiarity of the biological space-time is also connected with the evidently irreversible character of evolution and with the so-called *Dana generalisation* (J. Dana, 1813-1895). Studying the Crustacea, Dana (1972, pp. 1396-1397) formulated a principle: "the higher centralisation of the superior grades, and the less concentrated forces of the interior... This centralisation is literally a *cephalization* of the forces". Vernadsky (1991, pp. 21-22) reformulated this principle and stated that with the course of geological time the central nervous system of some species appear to be more and more perfect (*cephalization*). Human reason and a new level of organisation connected with it, are results of cephalization. The process of cephalization goes only in one direction and, hence, is expressed by the polar time vector, i.e. it is irreversible. The thesis of the irreversibility of evolution, in its turn, plays an important role in the theoretical apparatus of the *noosphere-concept* of Vernadsky (see 2.3.10. and 3.1.3.).

The impossibility of abiogenesis, as a general rule in the biosphere, also follows from his space-time theory (Vernadsky, 1965, pp. 24, 201). That is why the view of some authors, that Vernadsky by the end of his life was close to accepting abiogenesis, cannot be well-founded (Yanshina, 1994, p. 654, Yanshina, 1996, pp. 94-100).

It is also easy to see that the space-time theory plays a central role in Vernadsky's definition of the biosphere as a bioinert natural body (Vernadsky, 1991, pp. 167, 168) and not as an organism or super-organism as it is represented in the concepts of James Lovelock (1996) and Elisabeth Sahtouris (1996).

Ignorance of Vernadsky's space-time theory leads to incorrect interpretations of the important aspects of his theoretical system. For example, L. Margulis and D. Sagan (1995, p. 47) ignorant of Vernadsky's space-time theory claimed that „Vernadsky dismantled the rigid boundary between living organisms and a non-living environment.“ That is correct only in the sense that living matter is the most powerful geological force.

I generally agree with E. Sahtouris' view (1995), that Vernadsky's „concept of living matter is the same as Lovelock's concept of 'biota' - the sum total of living creatures, contrasted with the 'abiotic' or non-living environment.“ I do not agree, however, with her interpretation of the shades of meaning of these terms in the works of Vernadsky. Sahtouris maintains that in Vernadsky's concept of living and inert matter (biota and non-living environment), the emphasis is on geological continuity on each as a transformation of the other, whereas in Lovelock's concept, the emphasis is on their interaction as separate parts of a working system.

As we have seen, in Vernadsky's work, the living and the inert natural bodies of the biosphere are kept well separated from one another by the spatial-temporal specificity of living matter. The border is clear and sharp. Two worlds (living and non-living) are connected only by the biogenic flow of atoms (Vernadsky, 1988, p. 295). This flow of atoms, as the constant interaction between two kinds of matter, is essential precisely because of the separation of the two systems.

In conclusion, I would like to remark that the importance of the dissymmetry principle for Vernadsky can also be seen from another point of view. If we assume that this principle has the nature of a fundamental law, life would be a regular, non-sporadic, perpetual phenomenon in the Universe (Krumbein & Lapo, 1996, p. 127; Aksenov, 1996, p. 49).

2.2. PHILOSOPHY OF SCIENCE IN THE WORK OF V. I. VERNADSKY

2.2.1. *Introduction*

It was noted already (Kolchinsky, 1990) that some theoretical concepts of Vernadsky can be seen as inconsistent and controversial. Yet his philosophy of science is probably the most controversial part of his theoretical system.

Our main concern in this chapter is the reconstruction of the approaches to the philosophy of science of Vernadsky pointing out the role that philosophy of science plays in his whole theoretical system. Also some contradictions and inconsistencies in Vernadsky's philosophy of science will be shown.

2.2.2. *The nature of science: scientific thought as a planetary phenomenon*

The concept of scientific thought as a natural planetary phenomenon is the basic concept of Vernadsky's philosophy of science and is directly or indirectly connected with all parts of his theoretical system. How did he come to this idea? The most accentuated topics of Vernadsky were the idea of the cosmic nature of life (Aksenov, 1993) and the noosphere concept. Vernadsky deeply believed in the parish of a noosphere (see 2.3.10). Already in 1922, before he adopted the term 'noosphere' from Le Roy (during his staying in Paris), Vernadsky wrote in a letter to his son: „Besides, I believe and, moreover, scientifically know about the coming of great changes in the content of life due to the influence of the growth of scientific knowledge" (Kolchinsky, 1998, p. 9). Later he transformed this belief into the noosphere concept and tried to argue that this belief can be proved by means of the natural sciences he dealt with.

Science plays the main role in the noosphere: „The main geological force creating the noosphere is the growth of scientific knowledge" (Vernadsky, 1991, p. 43). The noosphere is a realm of science. In this connection Vernadsky mentions, not without reason, Plato's concept of a city-state controlled by scientists. In Vernadsky's case, the whole planet turns out to be a 'city-state'. The main objective of Vernadsky is to show the inevitability of the coming of the noosphere and to attach to this process the meaning of a natural process governed by natural laws. In line with this, he must legitimise the dominant role of scientific thought in the noosphere. And here the claim of the natural character of scientific thought is useful. The biosphere transforms itself into the noosphere with the help of scientific thought and it is a *natural process*. The more fundamental the role of living matter in the universe, the deeper the cosmic roots of science turn out to be. This point connects the idea of the cosmic nature of life and the philosophy of science of Vernadsky. In this context *natural* means for Vernadsky also *inevitable*, *lawful*. The process of transformation of the biosphere by scientific thought is a regular, directed process. In this point Vernadsky's philosophy of science overlaps his space-time theory, namely, the concept of dissymmetry of time.

Admittedly, one can pose the question: why is it scientific thought and not philosophical or religious thought that should most deserve our confidence? In order to answer this question, Vernadsky created the concept of the demarcation of science and non-science which I will discuss in the next section.

Vernadsky presents his mature concept of science as a natural phenomenon most extensively in the book „*Scientific Thought as a Planetary Phenomenon*" (1991, 1997), written in 1936-38. However, he started thinking in this direction much earlier. In a rough draft of the book about living matter (1916-17), he draws a parallel between the geochemical influence of living matter and the human influence on the geochemistry of

Earth (Sytnik et. al., 1988, p. 252). Ten years later (1927) in the plan for the unfinished article *„On the Border of Science. Space of the Natural Sciences and Space of Philosophy and Mathematics“*, Vernadsky (1988[1], p. 215) made one more step and noted: „Consciousness as a natural force“. This was 10 years before Vernadsky used the term „noosphere“ for the first time and in the same year when the term was first coined by Edouard Le Roy (Le Roy, 1927).

Vernadsky's concept of science as a planetary phenomenon develops along three basic lines:

1. If one takes into consideration the results of scientific creativity, science lies in the course of the natural evolution of the biosphere. The evolution of the biosphere moves in the direction of increasing the biogenic migration of atoms. Scientific thought accelerates powerfully the biogenic migration of atoms. Hence, the objective manifestations of science can be seen as the continuation of the natural course of the biosphere. Vernadsky (1965, p. 280) calls the biogenic migration accelerated by science *the biogenic migration of the third kind*. From this viewpoint, the history of humankind is interpreted as a natural phenomenon of great geological importance (Vernadsky, 1991, p. 39; 1997 p. 54).
2. One can point out the analogies between the evolution of species and the evolution of scientific thought (Vernadsky, 1991, pp. 43-44):

   „G. Sarton showed in his book, that since the VII century A.D. (taking into consideration 50-year periods and not only Western European civilisation but mankind in its entirety) *the growth of scientific knowledge was incessant*. And since then, with short intermissions, the rate of this growth was becoming swifter.

   It is curious that this is the same type of growth curve that one observes in the paleontological evolution of living animal matter, namely in the growth of the central nervous system“.
3. Scientific cognition as a geological process manifests „spontaneity“. This means that it is not an artificial, consciously programmed process. An example, of „spontaneity“ is the „explosion“ of scientific thought in the 20th century. The „spontaneity“ of this „explosion“ should serve as evidence of its naturalness and, hence, lawfulness: „'The explosion' of scientific thought in the 20th century was preceded by the entire previous history of the biosphere and has its deepest roots in that structure. It cannot cease and reverse“ (Vernadsky, 1991, p. 40). Vernadsky considers that in the growth of scientific thought in the 20th century, one can see its planetary, „alien to us“, character. He approaches the growth of science as a manifestation of the structure of the biosphere that reveals to us the new features of its organisation (Vernadsky, 1991, p. 39; 1997, p. 54).

Along these line Vernadsky comes to the following conclusions:

1. Scientific activity is the force by means of which man changes the biosphere in which he lives.
2. This manifestation of the change in the biosphere is an inevitable process accompanying the growth of scientific thought.
3. This biospheric change is a natural process and takes place independently of human will.
4. The appearance within the biosphere of a new modifying factor, that is, of the scientific thought of humanity, is a natural process of the transition of the biosphere into a new phase - the noosphere.
5. This reveals to us a new „law of nature“ (Vernadsky, 1991, p. 51; 1997, p. 69-70).

Our view is that this concept of Vernadsky follows his intuition rather than rationally-based conclusions. None of the three outlined ways of arguing were developed into a mature conceptual structure.

Argument (1) can be called a „biogeochemical argument". I examine this argument in the context of the noosphere concept in the section 2.3.10.

In order to examine this argument in the context of Vernadsky's philosophy of science, we can reverse the problem and pose the following question: what would the claim of the „non-planetary", „anti-natural" character of scientific thought mean? No natural scientist contests that the mental apparatus is the result of the evolution. Vernadsky argues that scientific thought is a natural (planetary) phenomenon because the process of scientific creativity lies in the main stream of the evolution of the biosphere. Hence, the origin and development of scientific thought must be determined by planetary (cosmic) laws. Accordingly, scientific thought would appear „unnatural" for Vernadsky, if it were opposed to nature in its manifestations. Vernadsky could not be unaware that such manifestations took place. He witnessed the First and Second World Wars. Science was placed at the service of obviously destructive forces. However, Vernadsky believed that all these are temporary deviations from the main stream of development of our civilisation, which he defined as the way to the noosphere. Any living being shows elements of *unnaturalness* because it is opposed to nature in the sense that it has an „ideal purpose" to concur with the whole planet and adapt it to its own service. If it happened, it would be fatal for a species. Nevertheless, any bacteria in the absence of natural restrictions would occupy the whole planet. L. Margulis and D. Sagan (1997) provide an illustrative example of the „unnaturalness" of natural processes in the history of the biosphere describing the „oxygen holocaust".

Where Vernadsky's philosophy of science evidently turns too speculative, however, is in holding that scientific thought is a natural and, hence, a *lawful* phenomenon. First, the quantitative characteristics of the biogenic migration of atoms as they are say little about the content of this process. The human mind differs from its environment with regard to its reflective nature which give humans a certain freedom of choice. The evident geological influence of humankind does not make the distance between man and nature shorter. Second, Vernadsky did not examine the question, whether the acceleration of the biogenic migration should have natural limits (see 2.3.10 for the details). Couldn't an extremely accelerated rate of the biogenic migration of atoms lead to the beginning of destructive processes? Shouldn't a period of intensive acceleration be replaced by a period of a stable rate of biogenic migration? Without answering these questions, we cannot judge the naturalness or unnaturalness of the geological influence of man.

Argument (2) in its most general form is close to the „weak" Popperian (1974) version of evolutionary epistemology. In both cases a parallel is drawn between the evolutionary process and the development of science. Vernadsky, however, does not draw the parallels with the processes of variation, selection and fixation as analogies to the scientific evolution. Theories and hypotheses play a secondary role in Vernadsky's methodological hierarchy. He mentions irreversibility and acceleration as analogies between the evolution of the biosphere and the evolution of science. However, these analogies are quite weak and do not prove that scientific evolution is the continuation of biological evolution. The analogies do not show that the two processes are akin.

Argument (3) is the weakest of the three outlined arguments. The „explosion" of scientific creativity in the 20th century is indeed a spontaneous process. It was not consciously programmed by humans. Yet this „explosion" can be explained from different viewpoints (e. g., theory of information, sociology) without resorting to geological explanations. This „explosion" cannot be seen as an evidence for naturalness of scientific thought. It is also not an argument in favour of lawfulness of the origin of scientific thought.

The basic problem of the whole complex of arguments is the vanishing of the border between naturalness and unnaturalness. Indeed, if human thought is natural, then there is nothing unnatural, nothing non-planetary on the planet Earth. Hence, there is no sense in opposing planetary and non-planetary phenomena. The category „unnatural" loses its sense. Disregarding such juxtapositions as Nature - Scientific Thought, Nature - Technology leads to the impossibility of recognising the sovereignty of Nature.

Vernadsky's claim (1991, p. 40) that man is „a definite function of the biosphere" and that he „in all his manifestations is a definite lawful part of the biosphere structure" can be compared with the concept of K. Marx that man is a function of the production relations. In both cases one is faced with the evident contradiction between the free will of man and his „functional" dependence on a superhuman phenomenon.

2.2.3. *The demarcation of Science, Philosophy and Religion*

The problem of the demarcation of science and non-science in the late (1930s - 40s) works of Vernadsky appears in connection with two objectives: (a) to show the privileged place of science among other forms of cognition and (b) to protect science against the encroachments of the Marxist-philosophers. However, in the relatively early works, written by the beginning of the 20th century, Vernadsky examined the problem of demarcation in close connection with the question of the mutual influence of science, philosophy and religion.

In 1902 Vernadsky wrote an article entitled „*On Scientific Worldview*" (Vernadsky, 1988[1], pp. 42-80). In this article he develops a relatively detailed concept of the demarcation of scientific knowledge from philosophy and religion and introduces the important notion of a 'scientific worldview' (Weltanschauung). Scientific worldview is, according to Vernadsky, a picture made of key scientific methodological principles, the most important generalisations and discoveries, and the laws of logic and mathematics. It is a certain attitude of the scientist toward the world which influences the development of science as a whole. The scientific worldview of a certain epoch inevitably contains errors. For example, the views of Ptolemeus on the Universe in his epoch were false as we know now, but it was, nevertheless, a *scientific* worldview (Vernadsky, 1988). Scientists, who worked in the frames of Ptolemean system, used strictly scientific methods and developed an extensive technology of scientific devices.

The most important aspects of our contemporary scientific worldview arose from religion, philosophy, art, and everyday social life. The aspiration of contemporary science to express everything in numbers came from music. The search for numerical harmony penetrated science in the form of a concept of music through the school of Pythagoras. Number plays in contemporary science the same mystic role as it played in antic religious cults. Scientific reason rests on its laurels when it finds numeric proportions. It is noteworthy that Vernadsky (1988, p. 54) remarks in this connection that the „mathematical constructions" are the „ideal creations of our reason". Thus the wide-spread concepts of contemporary science such as atom, energy, force, and heredity penetrated science from the other forms of intellectual activity.

At the same time, Vernadsky emphasises that non-scientific views have remained in science only because they went through the crucible of the scientific method. But what does „scientific method" mean? Vernadsky writes about inductive and deductive logic, empirical evidence for every scientific statement, and the logic of facts. But why do scientists believe in inductive logic? Vernadsky himself gives the example of Copernicus and Nikolaus Cusanus, who believed that a sphere would continue its move eternally being once moved, because the cause of movement is the form of sphere. It is evident now that they provided the wrong explanation, but they achieved their degree of understanding utilising strict scientific methods. Why should we believe in scientific method, if it provides the erroneous explanations? Surprisingly, this question does not arise in the early work of Vernadsky.

Examining the key concepts of modern science, he comes to the conclusion that the cessation of any creative function of the human mind (art, philosophy, religion) would retard the development of science. He claims that in the historical perspective, we do not know pure science without philosophy. Philosophy penetrates science and will never be replaced by science (Vernadsky, 1988).

The latter does not prevent Vernadsky from considering the principle difference between science, philosophy and religion. He claims that some aspects of the scientific worldview are generally obligatory for all people, for every philosophy and religion. Vernadsky considers these aspects as *scientifically valid parts* of a „scientific worldview". In contrast to science, neither various philosophies nor religions can be brought together to form a philosophical or religious unity.

All scientific claims which coincide formally with reality are obligatory for everybody (Vernadsky, 1988, p. 66). Vernadsky gives examples of such scientific claims: some statements of mathematics (2 x 2 = 4), the concept that the Earth moves around the sun and so on. It is noteworthy that some pages later, he gives an interesting example of an evidently true scientific concept: the wave theory of ether of O. Fresnel (1788-1827) and T. Young (1773-1829). This theory is regarded now as unnecessary. The example shows the main problem of Vernadsky's concept of scientific truth. In many cases it is difficult to be sure that we have enough evidence in order to say that our concept „coincide" with reality.

This early version of Vernadsky's concept of demarcation seems to be inconsistent. For example, he states: „A triumph of any scientific concept and the including of it into the scientific worldview do not prove its veracity" (Vernadsky, 1988, p. 71). Compare the latter statement with what he claims on the same page: „Scientific truths are incontestable" (Vernadsky, 1988, p. 71). Moreover, Vernadsky's claim of the indisputability of scientific truths which formally coincide with reality, is incompatible with his own attitude to what he calls *dualism*. He claimed that a strictly objective observation of the natural processes by a scientist is only a fantasy generated by the everyday scientific work (Vernadsky, 1988, p. 48). In reality a scientist is a part of the world he explores, a part of his research subject. But if a scientist is only a mutable part of the mutable world, how could he produce the immutable truths?

Vernadsky draws the demarcation line between science proper and non-science, and between science and philosophy in particular, somewhere inside of what he calls the *scientific worldview*. He emphasised that it is sometimes very difficult to identify this line: „Peering and going into a sophisticated mosaic of contemporary scientific worldview it is difficult to decide what in this worldview can be referred to as alien to scientific areas of human thought and what can be regarded as a result of pure scientific thinking" (Vernadsky, 1988[1], p. 416). All forms of spiritual activity play an important role in the development of science. Philosophy plays an especially important role: „An apparatus of scientific thought is crude and imperfect; it is improved, most of all, by means of the philosophical work of human consciousness" (Vernadsky, 1988, p. 72). In line with this, Vernadsky stressed in 1902 the importance of philosophy for the improvement of scientific methodology and places philosophy and religion partially inside the scientific worldview.

The mature views of Vernadsky on the problem of demarcation are presented most extensively in the book „*Scientific Thought as a Planetary Phenomenon*". During the years between these two works (1902-1938), Vernadsky founded geochemistry and biogeochemistry and created the biosphere and the noosphere concepts. It is interesting to note how his views on the subject changed over time.

In order to complete his biosphere-noosphere theory, Vernadsky needed a theory of science which could substantiate his claims about science as the unifying intellectual basis of the noosphere. He wrote: „We now go through an epoch of a major break through" (Vernadsky, 1991, p. 63) Vernadsky meant the transition to the noosphere. Philosophical thought showed its incapability for serving as a foundation of intellectual and spiritual unity. There is only one science for the whole mankind, while the philosophies are manifold and they have developed independently during the centuries (Vernadsky, 1991, p. 81). Besides, a philosophy is closely connected with the type of personality of its creator. Because of this, philosophy cannot solve the problems: „Philosophy never solves the enigmas of the world. It is looking for them" (Vernadsky, 1991, p. 77; 1997, p. 103).

Also religious spiritual unity is said to be an utopia. Neither can political thought lead to the unity of mankind. In the midst of spiritual crisis science manifested itself as a candidate for the role of the unifying factor. It is the best candidate, because, according to Vernadsky, science is an objective natural, geological force. It is the manifestation of the totality of human thought in human society (Vernadsky, 1991, p. 47). By the beginning of the 20th century, science manifested itself in two forms: a) in a form of logical obligatoriness and indisputability; b) in a form of 'universality' (from 'the Universe') as a force creating the noosphere.

Vernadsky develops his initial vague idea of the indisputable aspects of the scientific worldview into the concept of the indisputable aspects of science. The indisputability of science is tied up with a relatively small segment of scientific knowledge, which covers *logic, mathematics* and the *apparatus of scientific facts and generalisations* (Vernadsky, 1991, pp. 95, 96). Empirical generalisations build the foundation of science (Vernadsky, 1991, p. 96):

> „The main significance of theories and hypotheses is illusory. Notwithstanding their enormous influence upon scientific thought and scientific work at a given moment, they are always more transient than the indisputable part of science which represents scientific truth and survives hundreds and thousands of years, and is perhaps even a creation of scientific reason which transcends the limits of historical time (as something „eternal", invariable in geological time)."

In the course of time, theories and hypotheses will be replaced by empirical generalisations (Vernadsky, 1988[1], p. 281). At the same time, Vernadsky does not consider these „indisputable scientific truths" to be absolute truths: „In science we do not deal with absolute truths but with unquestionably exact logical conclusions and with relative assertions whose correctness varies within definite limits. Within the limits, these assertions are equivalent to the logically unquestionable inferences of reason" (Vernadsky, 1991, p.116).

Scientific apparatus is defined by Vernadsky's as follows: „I call 'scientific apparatus' a set of natural bodies and phenomena expressed with a quantitative or qualitative exactness and created in the 18th, and mainly in the 19th and 20th centuries as a base for all our scientific knowledge" (Vernadsky, 1991, p. 67; 1997, p. 91). Scientific apparatus, according to Vernadsky, was created in the last three centuries.

Logic, mathematics and scientific apparatus of empirical facts provide science with indisputable truths (Vernadsky, 1991, p. 93):

> „There is one radical phenomenon that defines scientific thought and distinguishes, clearly and simply, scientific results and scientific conclusions from the assertions of philosophy and religion: *this is the obligatoriness and indisputability of the correctly made scientific conclusions, scientific assertions, concepts and inferences*".

However, in contrast to the axioms of geometry, the obligatory nature of scientific truths is *not self-evident* and must constantly be reconsidered. This is the content of the everyday work of a scientist (Vernadsky, 1991, p. 94). This distinguishes science from philosophy and religion and this distinction puts science in a special place and defines its place in the noosphere. Due to this, science should be free of any form of control by philosophy or by religion.

With the exception of logic, mathematics, and scientific apparatus, the rest of science shows no indisputability. Science as it exists in reality is always penetrated by alien philosophical, religious, social and technical concepts. The revision of these concepts is the important task of the science history (Vernadsky, 1991, p. 47). In its entirety, science is not a logically coherent system of knowledge consciously determined by scientists. It is essentially a dynamic fluctuating equilibrium: „The system of science taken in its whole is always imperfect from the logical-critical viewpoint" (Vernadsky, 1991, p. 47). Only the rationalistic or mystic construction of the philosophical systems may be really logically well-balanced. Vernadsky (1991, p. 48) concludes: „Thus science is far from being a logical construction or truth-searching apparatus. One cannot perceive scientific truth by logic. It can be perceived only by life". Scientific thought develops in the midst of life and is inseparably tied to it. A professional scientist is only one of the creators of science. Sometimes the crucial hypotheses, theories, and generalisations were made by individuals who were led by considerations alien to science. In this context, Vernadsky introduces the term '*environment of science*'. The term implies not only scientific search of separate individuals alien to science, but also the influence on science of the important social and cultural events (e. g., the discovery of America, the fall of the Persian Kingdom and of the Chinese empires, the victory of the Christian churches). Thus, a part of scientific creativity proceeds from activity outside the consciously organised scientific work. Science cannot exist without simultaneously existing scientific organisation and scientific environment (Vernadsky, 1991, pp. 48-49). It also cannot exist without philosophy, because philosophical analysis of the abstract scientific notions is necessary for the scientific investigation of new research areas.

Thus, Vernadsky repeated some of his claims about the importance of philosophy to the development of science which he made in 1902. However, in the 30s he tried to take both philosophy and religion out of the context of science: „The primacy of scientific thought in its area, that is in scientific research, always exists independently of whether this primacy is recognised or not. Proper scientific statements are generally obligatory. This does not depend upon our will" (Vernadsky, 1991, p. 46).

In his concept of 'scientific worldview' (1902), the co-existence of science and philosophy *inside* the scientific worldview was a norm of scientific development. In that time Vernadsky stressed many times the impossibility of taking philosophy out of the context of science. By contrast, in 1938 he emphasised the primacy of science in its realm and placed philosophy not inside of the *scientific worldview* but outside of science, in the *scientific environment*. He abandoned his concept of the 'scientific worldview' in order to show more clearly the principle difference between science and other forms of cognition. This is tied up (1) with the role of science in the noosphere-concept and (2) with attempts of Vernadsky to defend science from the invasion of Marxist philosophers.

Our view is that the contradictory character of Vernadsky's concept of demarcation manifested itself in 1938 in the noosphere concept even more clearly than in 1902.

First of all, his claim of the indisputability of logic and mathematics can be opposed to his views on the nature of scientific thought. Human reason is subject to evolution: „...Even now one may ascertain that the main principle of every philosophy, the absolute immutability of reason and its effective inalterability, does not correspond to reality" (Vernadsky, 1991, p. 69; 1997, p. 93-94). According to Vernadsky, *Homo Sapiens* is not the crowning point of creation, the owner of a perfect thinking apparatus. He is only an intermediate link in a long chain of beings which existed in the past and will exist in the future. For a naturalist, human reason is only a transient phenomenon of the cognitive apparatus in the biosphere (Vernadsky, 1991, pp. 100-101).

Such views of Vernadsky might lead him to extreme forms of relativism, but in the case of Vernadsky, they co-exist peacefully with the conclusion about the indisputability of logical and mathematical truths. Partly it is due to the specific concept of logic which was elaborated by Vernadsky (see below: 2.2.4).

Further, Vernadsky's views on demarcation contradict his own concept of scientific thought as a planetary phenomenon. Scientific thought is, according to him, a function of the biosphere. In line with this, he makes the inference that logic of natural science is also a function of the biosphere and is closely connected with this geological envelope (Vernadsky, 1988, pp. 282-283). This means that this logic, which Vernadsky proclaimed as incontestable, should be adapted, first of all, for the cognition of that part of reality where and when it functions. One cannot be sure that this logic provides us with knowledge of more fundamental nature then theories and hypothesis. The „empirical generalisations" made by means of this „logic" must be as transient as theories and hypotheses. Vernadsky seems to be aware of this. He writes: „They [empirical generalisations - *auth.*] constantly change and deepen with the course of the development of natural science" (Vernadsky, 1988, p. 280). However, Vernadsky did not pose the question: how may empirical generalisations constantly change and be, at the same time, constantly indisputable? What does it mean to be indisputable in that sense? He also did not answer the question: why should we take the statements of mathematics as indisputable? Are mathematical and logical theories and hypotheses fundamentally different from theories and hypotheses of, for example, physics?

Thirdly, Vernadsky did not elaborate the problem of the connection between the „indisputable" parts of science and its disputable parts, i.e. theories and hypotheses. How could a science constituted by logic, indisputable statements of mathematics and „empirical generalisations" evolve? Vernadsky stresses that theories and hypotheses sometimes help us to get empirical generalisations, but where is the border between the empirically based theories and empirical generalisations? Why should we believe that mathematics and logic are able to reflect „objective reality" and operate properly with empirical facts? After all, what does „empirical fact" mean? It is noteworthy that in a little article written between 1920 and 1927, Vernadsky remarked (1988[1], p. 217):

> „Everyone of us knows how incomplete, insufficient and only partially reflecting of reality are all mathematical and logical rules having been elaborated by centuries-old scientific and philosophical work. Every attempt to achieve a complete logical definition of the conditions for discovery of a scientific fact as well as the attempts to define what a scientific fact is and what it is not doomed to failure".

How can one reconcile the above with the thesis of incontestability of mathematics (Vernadsky, 1991, p. 107)? Moreover, Vernadsky stressed many times that natural science as a whole must be logically incoherent, because our logic is only a „rational net", which we throw on reality.

Vernadsky does not answer these questions. He, plausibly, did not realise the difficulties of his theory of demarcation, because he was concentrating on the elaboration of the noosphere project. According to this project, he had to find a durable foundation for the future consolidation of mankind in the noosphere. He saw science as the candidate to play this role. That is why the claims of science must be widely acceptable, indisputable and detachable from the propositions of philosophy and prophecies of religion. On the other hand, he had to show that science is a natural phenomenon and, hence, the appearance of the noosphere will be a natural, inevitable process. Vernadsky was not successful in combining these two ideas within the framework of his theoretical system.

2.2.4 *Logic and Methodology of Science*

2.2.4.1. *How does science obtain its knowledge?*

The views of Vernadsky on logic and methodology of science are vague and sporadic and it is difficult to reconstruct them and present them as a unified detailed concept. He never had the aim to create a systematic logic and methodology of science, although he planned to write a special article (Vernadsky, 1988[1], p. 437) on the subject and made some extensive comments about it (Vernadsky, 1988[1], pp. 198-203). In his late works, Vernadsky once again came to this problem and, thus, in his different works, one can find his statements on the logic and methodology of science. I will, first, gather his statements on the subject and they will be briefly analysed.

Vernadsky (he mentions in this connection Ch. Peirce's (1839-1914) *Principles of Philosophy*) holds that there are two kinds of logic in science. The first kind of logic originates with Aristotle. This is a logic of words, a logic of reasonings. This is a logic of common sense elaborated by generations of the Greek philosophers. It has prevailed in Western Europe for centuries.

The second kind of logic originates from Democritus. It is a logic of things, the logic of natural bodies as contrasted to the logic of words. This logic describes the real relationships between natural bodies and their place in the structure of natural science. The meaning of a term (word) in this logic can evolve in the course of time, sometimes with remarkable speed. For example, the meaning of the term 'water' in the usage of Van-Helmont (1577-1644) differs from the term 'water' as we use it today (Vernadsky, 1965, p. 175). The example shows how one term can have two different meanings and, hence, what seems to be logical in operating with the first meaning of the word can be illogical in operating with its second meaning. Following, the logic operating with the concepts-things must be distinguished from the logic operating with abstract notions (Vernadsky, 1991, p. 116). It is this logic of the concepts-things that is proper to descriptive natural science. Vernadsky claims that it is not what the philosophers, for example, J. S. Mill (1806-1873), call an *inductive logic*. Naturalists, who use this logic spontaneously, come once again to this method examining natural bodies using scientific symbols and terms. Vernadsky gives one more example of the difference between the two forms of logic: the concept of space-time. Philosophers analysed the properties of space and time by means of the analysis of the words „space" and „time". Analysing these words, they could also come to the concept of space-time (Palagyj), but the statements of philosophy are not provable by means of philosophy itself. Only scientists succeeded in proving the existence of a real unified, all-embracing space-time, above all, by their everyday scientific work. Vernadsky sees in this point the difference between the logical work of the scientist and that of the philosopher. The latter cannot come out of the limits of the concepts-words (Vernadsky, 1991, p. 151).

In addition to Ch. Pierce, who has not elaborated the idea of the two logics systematically, Vernadsky was evidently influenced by the ideas of H. Bergson. Bergson stated (1969) that our logic has been developed on the basis of symbols reflecting the relationships between rigid natural bodies. However, in contrast to Bergson, Vernadsky extended this idea to all kinds of natural bodies.

Vernadsky's idea of the logic of concepts-things is based on his notion of *empirical generalisation*. An empirical generalisation is a generalisation based on empirical facts which does not go further than the facts themselves and follows the logic of the relationships between the natural phenomena. Every new concept, which is put forward by an empirical generalisation is logically obligatory. If an empirical generalisation contradicts a theory, one must change or give up the theory. Vernadsky distinguished two kinds of empirical generalisations. Generalisations of the first kind are extracted from the „raw material of empirical facts" and have nothing in common with the inductive logic of philosophy (Vernadsky, 1988[1], p. 287). This kind of empirical generalisation composes, for example, the great bulk of crystallography as a modelling of the ideal natural and synthetic crystals. The principle of symmetry and the periodic system of D. Mendeleev are examples of empirical generalisations of the first kind.

Vernadsky did not give a clear definition of empirical generalisations of the second kind. However, the whole way of his thinking shows that by generalisations of the second kind he meant the generalisations made on the basis of empirical generalisations of the first kind (generalisations made on the basis of the „raw" empirical facts). An example of such a generalisation is the following statement: „There are no transitions between the living and inert bodies of the biosphere; the boundary between them is sharp and clear throughout geological history" (Vernadsky, 1991, p. 167). This generalisation is based on some other empirical generalisations such as the generalisations of spatial, temporal, energetic, and chemical properties of living and inert natural bodies.

Vernadsky also used the term „empirical principle", which can be defined as the most „general" generalisation of the second kind. He stated that three empirical principles lay in the foundation of the contemporary natural sciences (Vernadsky, 1980, p. 112):

- the Principle of conservation of mass (Newton, 1678);
- the Principle of the Cosmic nature of life (Huygens, 1695);
- the Principle of conservation of energy (Sadi Carnot, 1824; J. R. Mayer, 1847)

Our view is that Vernadsky's classification of empirical generalisations is very conditional. If we thoroughly examine the process of generalising a group of scientific „facts", we find that one can classify generalisations into the first, second, third, ... ∞ kinds. For example, in order to make a model (empirical generalisation) of any kind of crystals, one has to have at his disposal the generalisations of mathematics, the concepts of isotropy and anisotropy, the concept of atom etc.

In Vernadsky's view, empirical generalisations compose the foundation of science. They are incontestable and obligatory for everybody. At the same time, empirical generalisations are not immutable. Vernadsky gives an example of the evolution of an incontestable empirical generalisation: D. Mendeleev (1834-1907) discovered a periodic system of the chemical elements (1869) and it was a pure empirical generalisation, but eight years after his death the discovery of H. Moseley (1887-1915) changed our understanding of this generalisation by introducing the concept of the isotope. Moseley did not disprove the generalisation of Mendeleev, but made our understanding of this generalisation deeper.

Thus the foundation of science consists of empirical generalisations which are made by means of the peculiar „logic of things". In the absence of sufficient empirical data, a scientist can build theories and hypotheses, but they are only the provisional manifestations of the scientific knowledge and play a secondary role in the development of science. Only empirical generalisations constitute incontestable scientific knowledge. However, Vernadsky continues, the detailed examination of empirical generalisations shows that even they are only partially incontestable. If one follow this line, we find that, ultimately, only an ill-defined core of empirical generalisation turns out to be an incontestable component of science. But how can this core be defined?

In addition, Vernadsky (1988[1], p. 280) claims that the laws of natural logic must differ in the different geological layers of the Earth. Our thinking apparatus is adapted to the biosphere and can perceive the reality outside the biosphere only in terms of mathematical symbols. One cannot clearly imagine the things which are represented by these mathematical symbols.

Vernadsky stressed many times that his logic of things should meet the requirements of biogeochemistry and the biosphere theory. Specifically, he wrote, this logic should take into account that the biosphere, as a whole, is reflected in every scientifically significant biospheric phenomenon (Vernadsky, 1988[1], p. 202). Vernadsky's thinking here tends in the direction of the general system theory and mathematical modelling of the biosphere. But at his time, he could not complete this project. This approach to the biospherical problems was applied later by his followers (Moiseev et al., 1985).

Some remarks should be made in connection with Vernadsky's concept of the structure of scientific knowledge.

The main problem of Vernadsky's concept of scientific knowledge is his definition of the logic of things, which he refers to as the fundamentals of natural science. This view implies that there is a „natural" logic of the relationships between natural bodies (things) and that a scientist should „only" be constantly improving the methodology of reflecting these „real" relationships. However, it is not enough to declare that your basic method is empirical generalisation. The more important thing is to prove that your concept (empirical generalisation, theory, etc.) actually reflects the „real logic of real things".

Furthermore, Vernadsky's concept implies the assumption that in the foundation of our world lies a universal logic. Thus Vernadsky's attempt to escape the metaphysical claims of science by means of his „natural logic" lead back to necessity for a metaphysical substantiation of his logic of things.

The belief that a certain logic forms the basis of the world (Vernadsky, 1988[1], p. 306) is a metaphysical belief. Vernadsky declared that a science composed of empirical generalisations cannot escape contradictions. The contradictoriness of science results from the contradictoriness of the universe itself. However, if we admit that there is no universal „natural logic" and empirical generalisations only reflect (register) the connections between different things in the different parts of the universe, and if these „reflections" are altering together with the alteration of the world, can we define these „reflections" as knowledge?

The next problem is that Vernadsky's theory of the biosphere does not correspond to his own concept of the structure of scientific knowledge. He did not succeed in creating a theory based on empirical generalisations. Ultimately, he was forced to give the status of empirical generalisations to the purely metaphysical claims. Now, fifty years after Vernadsky, one can state that many of his „empirical generalisations" were not more than scientific hypotheses with a poor empirical content or, even, metaphysical statements. In the note „*On the Geological Significance of Symmetry*" (1941-1942), Vernadsky provides a kind of summary of his basic empirical generalisations. I provide some examples of these „empirical generalisations", to show that they were nothing more than hypotheses:

- An invariability of the weathering processes is followed by the inference about the constancy of the amount of living matter on the Earth throughout geological history (Vernadsky, 1988[1], p. 285);
- In the living matter we can directly observe space-time (Vernadsky, 1988[1], p. 285).

However, the most illustrative example is Vernadsky's statement that the logic of natural science is a function of the biosphere. He called this claim the basic empirical generalisation of his biosphere theory (Vernadsky, 1988[1], p. 283). It is evident that there are no ways to prove this claim by observation or by experiment. At the same time, this claim plays a central role in Vernadsky's concept of the transition of the biosphere into the noosphere.

The next point that Vernadsky failed to notice is that, if the logic of natural science is a function of the biosphere, then one cannot treat empirical generalisations (made by means of this logic) as incontestable. Moreover, this functionality transforms empirical generalisations into theoretical concepts. This was noticed by K. Popper (1968, p. 163):

> "...We always operate with theories, some of which are even incorporated in our physiology. And a sense-organ is akin to a theory: according to evolutionists views a sense-organ is developed in an attempt to adjust ourselves to a real external world, to help us to find our way through the world. A scientific theory is an organ we develop outside our skin, while an organ is a theory we develop inside our skin. This is one of the many reasons why the idea of completely untheoretical, and hence incorrigible, sense-data is mistaken".

One could note that Vernadsky never directly connected scientific knowledge with the sense-data, however, the thought of Popper can be adopted for our purposes: if science is an evolutionary-developed function of the biosphere, then its „empirical generalisations" will be theoretical as well as „theories" and one loses the necessity to distinguish between „theories" and „empirical generalisations".

One more problem arises in this connection. If we accept that the cognitive apparatus of science is a function of the biosphere, then we are in no position to make incontestable empirical generalisations about the non-biospheric imperceptible mechanisms of the universe. On the one hand, in the terms of modern philosophy of science, most of Vernadsky's claims about scientific knowledge are *realistic*. He believed that empirical generalisations can be regarded as accurate descriptions of the unobservable world as well. On the other hand, Vernadsky held that scientific thought is a function of the biosphere. The logic of science is different in the different geological layers and is a „rational net" thrown on reality. In the latter case, Vernadsky provides grist for the mill of *instrumentalists*, who hold that we cannot make firm judgements about imperceptible mechanisms. (Note that the biosphere as a self-regulating system is still an imperceptible mechanism.)

2.2.4.2. *Life sciences and the problem of reduction*

The problem of reduction in relation to the life sciences deals with the question of whether biological phenomena, laws and theories can be accounted for by physical science (Rosenberg, 1985, p. 69). Vernadsky worked on the border between the life sciences, chemistry, and geology and never numbered himself among the biologists. That is why it is specially interesting to look briefly over his views on the problem of reductionism.

In the article „*The Beginning an the Eternity of Life*" (1922), Vernadsky contrasts his position to the philosophical views of G.T. Fechner (1801-1887) and H. Bergson (1859-1941). Bergson and Fechner declared the eternity of life as a principle in the Universe. At the same time, they held that, although life generally is an eternal phenomenon, life in form of a living organism appeared at a certain time as a result of the *world process*. From this, they disassociated the concept of life from the concept of the living organism. This line leads to the idea of similarity between living and inert bodies and, ultimately, to the erosion of the principle of life. That is why Vernadsky, on the one hand, accepted the idea of eternity of life of Bergson but, on the other hand, stated that there is an impassable border between living and inert matter, because life can exist only in the dispersed form of living organisms. According to the philosophical systems of Fechner and Bergson, one could expect a constant transition of living natural bodies into inert natural bodies and back. However we have never observed transitions of inert natural bodies into living bodies. Vernadsky emphasised that the idea of the beginning of life is a purely philosophical idea.

He states that the philosophical atmosphere of the 19-20th centuries, which also penetrated science, generated an idea of applying the methods and logic of physics and chemistry to the investigations of living organisms and reducing the biological processes to the processes of chemistry and physics. „This aspiration", wrote Vernadsky (1994, p. 95), "is not well-founded and did not follow the empirical data of science. We should look for the genesis of this view in the history of philosophical thought". Thus, Vernadsky tied up his antireductionist position with the idea of the eternity of life and the *Redi principle*. Later, when Vernadsky elaborated the main principles of his biosphere-theory, his antireductionist views turned out to be tied up with the empirical generalisations on the difference between living and inert natural bodies (Sytnik et al., 1988, p. 143) and, hence, with the basic principles of the biosphere theory. The idea of the fundamental differences between living and inert natural bodies and the akin idea of the non-reducibility of the properties of living matter to the properties of inert matter are clearly expressed by Vernadsky also in his latest works (e.g., 1991, p. 167).

2.2.5. *The Empiricism and Positivism of Vernadsky*

2.2.5.1. *Empiricism*

Here I defend the thesis that Vernadsky's philosophy of science is a version of radical empiricism. At the same time, the radical empiricism of Vernadsky is inconsistent empiricism.

Some authors have already noticed that the philosophical views of Vernadsky can be classified as radical empiricism (Aronov & Terentjev, 1988, p. 72). These authors were strongly criticised by pointing to quotations from Vernadsky where he declares the importance of theoretical knowledge for the development of science (Shinkaruk, 1988, pp. 128-132). Here I participate in this discussion.

Radical empiricism was very popular among the natural scientists in the first third of the 20th century. Its basic ideas were articulated by Ernst Mach (1838-1916). Some of his ideas were further developed by the *Ernst Mach Verein*, which is better known as the Vienna Circle. The claims that the only role of philosophy is clarification of the meanings of statements and that there are only two sources of knowledge, namely, experience and logical reasoning are very close to Vernadsky's views. I do not find any traces of the direct influence of logical positivism on Vernadsky, but he was aware of the writings of Mach and other radical empiricists. It is interesting to compare the views of Vernadsky and Mach, because it can shed light on the problem of closeness of Vernadsky to radical empiricism.

Mach declared the description of one's sensations to be the only proper function of science. Prediction, explanation, and scientific laws and theories are considered by Mach as the forms of description. According to Mach, the law is as essential as the sum of the separate facts. Causal explanations are only descriptions of real factual dependencies between things. At the same time, Mach (1987, p. 271) distinguishes direct and indirect descriptions. Theoretical knowledge Mach considers as the indirect descriptions. Indirect description (theory) deals with a kind of theoretical substitution (fact B) of an empirical fact (fact A). From this, according to Mach (1987, p. 278), it seems to be not only desirable but even necessary to replace indirect descriptions with direct descriptions as far as possible.

It is easy to see similarities between the philosophical views of Vernadsky and the radical empiricism of E. Mach. Mach's summarising (1987, p. 270) of the procedure of the 'scientific description' seems to be very similar to Vernadsky's definition of the empirical generalisation of the first kind. In both cases, the scientifically significant features of things are directly abstracted from raw facts by means of their comparison (compare with Vernadsky's example of empirical generalisation in crystallography). In both cases, science turns out to be a one-dimensional structure, where all forms of theoretical knowledge are seen as provisional and must be replaced in the course of scientific development by pure empirical knowledge: empirical generalisations (Vernadsky) or the direct descriptions (Mach). In both cases, the claims of science are tentative but its method is impersonal. Clearly, Vernadsky never proclaimed anything like Mach's concept of the elements and never directly reduced scientific experience to one's sensations. It is on this ground Mach never accepted the reality of atoms. Vernadsky, on the contrary, based his concept on faith in their reality. Nevertheless, in both cases, pure experience is the epistemic base. However, in distinction to Mach and other philosophising naturalists, whom he mentions (e. g., A. Eddington: see below) Vernadsky never detailed his concept of experience and observation. He stressed many times that the only source of true scientific knowledge is empirical generalisation.

Empirical generalisation, in its turn, is the result of direct or indirect observations. Direct observations can be made only in the biosphere and, hence, our knowledge of the biosphere is the most deep and fundamental. Indirect observations cannot be directly perceived and imagined by a scientist, but can be expressed in mathematical symbols. Vernadsky never expressed clearly his views on the nature of mathematical knowledge, but the whole way of his thinking leads to the conclusion that mathematics should operate with the abstracted features of „real things" as well, i.e. can be ultimately reduced to scientific experience. Also the proper „logic of natural science" of Vernadsky reflects the real relationships between natural bodies and, hence, can be seen as similar to Mach's descriptions of the real factual dependencies between things.

Vernadsky, evidently, did not grasp the similarities between his views and the ideas of radical empiricism, although, as I already noted, he was very aware of the works of E. Mach and other scientists and philosophers, who shared the ideas of radical empiricism. One finds in Vernadsky's writings references to, for example, K. Pearson (Vernadsky, 1994, pp. 57), M. Verworn (Vernadsky, 1994, p. 251) and Mach himself (Vernadsky, 1965, p. 176; Vernadsky, 1980, pp. 99, 152; Vernadsky, 1988, p. 69; Vernadsky, 1988[1], pp. 240, 322, 329; Vernadsky, 1991, p. 222; 1994, pp. 257). However, Vernadsky never refers to their views in connection with his philosophy of science. Moreover, he points out that empirio-criticism does not correspond to scientific data and shows his sympathy to the empiricism of Ch. Pierce and especially of Arthur Eddington (1882-1944). He writes: „In distinct to empirio-criticism of Mach, the empiricism of Pierce as well as the scientific theory of knowledge of Eddington, correspond to the new scientific achievements. The other new and old streams of philosophy disagree with these achievements" (Vernadsky, 1980, p. 99). In another place, Vernadsky (1965, p. 164) states that Eddington transformed epistemology into a scientific (in contrast to philosophy) discipline by connecting its inferences with experience and observation.

One can wonder why Vernadsky, who was so accurate concerning the history of ideas, never mentioned Mach in connection with his radical empiricism. Perhaps, he did not realise the philosophical consequences of his views. Besides, Vernadsky was aware of the anti-atomistic prejudices of Mach which could be a good reason for Vernadsky's branding of Mach's empiriocriticism as not compatible with the scientific data. Looking for philosophies corresponding to his own views, Vernadsky finds the epistemology of Eddington and the philosophy of Peirce. He mentions Peirce's „*Principles of Philosophy*" and his article written together with Christine Ladd-Franklin (1847-1930) for the „*Dictionary of Philosophy and Psychology*" (Baldwin, 1901). Vernadsky probably knew that Peirce was the founder of pragmatism, which received recognition due to the radical empiricism of W. James (1842-1910). In spite of some references to Peirce, I do not find any traces of significant influence of pragmatism on Vernadsky's philosophy of science.

As to Eddington's epistemology, Vernadsky was probably attracted by Eddington's attempt to create an epistemology based on the researching of a specific natural science (physics) and, of course, by the empiricism of Eddington. Vernadsky (1965, p. 164) believed that Eddington created (or tried to create) a „scientific epistemology" derived from scientific experience and observation. Indeed, Eddington (1949, p. 19) emphasised that observation is the supreme court for the truth of physical knowledge. At the same time, Vernadsky seemingly did not grasp the difference between Eddington's and his own views on the nature of scientific knowledge. In spite of his empiricism, Eddington was convinced that the mind fits empirical data into a pattern determined by the nature of the cognitive apparatus itself. At the same time, there are no traces of apriorism in the epistemology of Vernadsky. Vernadsky did not realise that the empiricism in Eddington's philosophy was restricted by apriorism and „subjective selectivism" (Eddington, 1949, p. 7). The difference between their views can be illustrated by their attitude to the relativity theory. Eddington (1949, pp. 110-111) claimed that the special relativity theory is true and occupies an especially honoured place among other theories precisely because it is free of personal subjectivity and because it can be deduced a priori from the epistemological facts. Vernadsky (1991, p. 68), on the contrary, stated: „The theory of relativity is permeated by extrapolations and simplifications of reality, by admissions, whose verification by scientific experience and scientific observation (from the viewpoint of the noosphere) remain for the time being impossible. Owing to that, it occupies only a negligible place in current scientific research".

Thus, I maintain that, in spite of Vernadsky's critical remarks about Mach's version of empiriocriticism and declaring of sympathy toward the empiricism of Peirce and epistemology of Eddington, Vernadsky's philosophy of science has some important similarities to Mach's radical empiricism and has much less in common with the philosophies of Peirce and Eddington.

Vernadsky's ignorance of similarities between his philosophy of science and radical empiricism can be explained as follows:

a) Vernadsky was inconsistent in his philosophical views and did not grasp the closeness of his viewpoint to radical empiricism. Vernadsky (1991[1], p. 33) classified himself as a philosophical sceptic and believed himself to be purely scientific and independent of any philosophy (Ghilarov, 1994).
b) Vernadsky was influenced by radical empiricism mostly indirectly, via the whole philosophical atmosphere of the first third of the 20th century, when empiricism was widespread among philosophically-aware natural scientists.
c) As well as Mach, Vernadsky derived his views on the nature of scientific knowledge to a great extent from his experience as an empirical scientist. As I have shown, his concept of science was also influenced by his noosphere concept. But some basic postulates of his philosophy of science were formulated long ago he created the biosphere-noosphere theory.

The inconsistency of Vernadsky's empiricism manifests itself in his views on the nature of scientific facts. According to him, the incontestable part of science consists of three parts: the scientific apparatus of facts, logic and mathematics. However, a scientific fact is not a fact of everyday life. A scientific fact is a mathematically-processed and systematised fact (Vernadsky, 1980, pp. 108-109). Hence, any fact constituting scientific apparatus already contains a large portion of theory and cannot be seen as a purely empirical fact.

At the same time, Vernadsky (1980, pp. 92-93) believed that mathematics and logic were ultimately transformed empirical knowledge as well. Thus mathematically-processed empirical data lie in the foundation of mathematics. But what does this 'mathematically-processed and systematised' mean? In order to answer this question, we should recognise that an empirical fact in the scientific apparatus is not completely empirical, but a theoretically-processed fact. However, in this case, we are faced with the difficulties of explaining the nature of theoretical knowledge as contrasted to empirical knowledge. Vernadsky failed to explain the nature of theoretical knowledge.

2.2.5.2. *Positivism*

In the already mentioned work „*On Scientific Worldview*" (1902), Vernadsky (1988, p. 61) defined positivism as a scheme which has nothing in common with reality. He meant the positivism of A. Comte (1798-1857), whose philosophy Vernadsky had thoroughly studied already in his youth. Comte claimed that the development of human knowledge passes through three stages: the theological, the metaphysical and the positive (scientific) stage. Vernadsky defines this 'scientific' claim of Comte as non-scientific, because it does not correspond to observations of the real scientific process. In reality, all three of these forms of cognition co-exist with one another and, moreover, science cannot be separated from philosophy and religion because of the unity of human consciousness. Thus, already in 1902, Vernadsky dissociated himself from the positivism of Comte. Nevertheless, an outstanding historian of Russian philosophy, V. Zen'kovsky (1881-1962) (who was also a friend of Vernadsky), numbers Vernadsky among the positivists (Zen'kovsky, 1950, p. 259) based mostly on the above mentioned work (1902) in which Vernadsky declared himself to be non-positivist. Why does Zen'kovsky refer to the philosophy of science of Vernadsky as positivism? The question sounds even more intriguing if we note that Zen'kovsky was not aware of the most positivistic works of Vernadsky, his latest works, which were only recently published. Our answer to this question is: Vernadsky understood positivism too narrowly, i.e. only as the concept of three stages of A. Comte. He did not realise that his own view on science and human history can be classified as positivism in a broader sense. At the same time, some important features of what is generally known as the positivistic approach can be found in Vernadsky's late writings.

- Vernadsky shared a positivistic trust in logical and mathematical methods. However, as we have seen, his understanding of logic is quite original. He stated that both the inductive logic of J. S. Mill and philosophical logic are alien to exact science. However, he believed that proper logic and mathematics reflect the properties of the real observable world.
- Vernadsky was convinced that only a science founded on empirical methodology can answer the basic questions of the Universe, while philosophy can only help in posing these questions and clarifying the terminological problems. Any philosophy reflects the individual worldview of the philosopher and cannot form a basis for incontestable knowledge (Vernadsky, 1991, p. 77). Thus, he also shared scientism in common with the positivists, although in distinction to most positivists, he believed that philosophy possesses a different method of cognition from science. The question arises in this connection whether the method of philosophy leads to any knowledge if it expresses only the individual worldview of a philosopher? We must keep in mind that one finds in the texts of Vernadsky also statements emphasising the important role of philosophy for the development of science. Thus, in one of his late works, Vernadsky (1988', p. 314) writes: „Scientific thought cannot function without philosophical work. It cannot intensively and deeply elaborate scientific hypotheses, theories, and cosmological constructions". At the same time, Vernadsky declares that not only philosophical achievements but also scientific theories and hypotheses play a secondary role in science and that „in the basis of natural science lie *only* scientific empirical facts and scientific empirical generalisations" and that in the course of scientific development, we must strive to replace scientific theories „with empirical facts and empirical generalisations as soon as possible" (Vernadsky, 1988', p. 281). Neither theories nor hypotheses are

characteristic to science and play, together with philosophy, a subsidiary role in scientific development.

- Vernadsky's scientism and, at the same time, undisguised „anti-theoretism" are connected with his phenomenalism. As a rule, „empirically-substantiated empirical generalisations", which compose the foundation of science, do not go further than the phenomena. For example, summarising in *„Scientific Thought..."* the most important empirical generalisations about living and inert matter, Vernadsky (1991, p. 173).writes: „All the generalisations indicated here do not transcend the phenomena that may be observed in the life of organisms and their complexes. These generalisations do not refer to life and do not explain it. They only tie together the facts and give logical inferences from the scientific description of reality".
- In the noosphere concept, Vernadsky combines the claims of both social and evolutionary positivism. He mentions the founders of the positivistic concept of progress Ch. Lyell (1797-1875), Herbert Spenser (1820-1904), H. de Saint-Simon (1760-1825), J. S. Mill (1806-1873), Jeremy Bentham (1748-1832) many times in his works. The idea of an unlinear, continuous and necessarily progressive evolution influenced Vernadsky's theory of the directed evolution of the biosphere towards the noosphere. The theory is geologically - and biologically - based, but leads as well to declaring the inevitability of social progress connected, in its turn, with the progressive development of science as a planetary phenomenon. The noosphere turns out to be the crown of biological and social evolution.
- Vernadsky viewed the Universe from the atomic viewpoint which makes his position akin to the positivistic account. However, an important difference should be pointed out. In the classic works of positivism, this account comes from the nominalistic approach. In the worldview of Vernadsky, atomism is based on his biogeochemical experience rather than conscious nominalistic beliefs.

Thus, I classify Vernadsky's philosophy of science as a positivistic philosophy, although, as I pointed out, in the writings of Vernadsky one can find statements, which are not in agreement with the most influential positivistic schools of his time. For example, in contrast to E. Mach and the Vienna Circle, Vernadsky emphasised many times the importance of philosophy for science and never directly declared that metaphysics (philosophy) is meaningless or has no true claims to be considered as knowledge. At the same time, Vernadsky would doutlessly subscribe the conclusion of Mach that metaphysics has no grounds for its claims for certitude (Cohen, 1970, p. 128), while the proper scientific method provides a certain incontestability. Does this mean that science provides some incontestable knowledge of the external world, while philosophy does not? A positive answer would reduce the importance of philosophy to the role of an auxiliary instrument of science. This estimate of the importance of philosophy was accepted even by the extremely anti-metaphysically disposed logical positivists (Schlick, 1930). Some of the last statements of Vernadsky (1980, p. 87) show that he was deeply dissatisfied with contemporary philosophy and wanted to transform philosophy into an empirical science.

2.2.5.3. *Departure from positivism*

In the case of Vernadsky, it is important to distinguish between his expressed philosophical views on science and the philosophical position and methodology which

Vernadsky practically applied in constructing the „empirical" parts of his theoretical system.

Vernadsky considered himself a philosophical sceptic: „I am a philosophical sceptic. This means that I consider that not one philosophical system (including our official philosophy) has achieved that eternal applicability which science (and only in several specific areas) has achieved" (Vernadsky, 1933, transl. by K. Bailes, 1990, p. 163).

I considered Vernadsky's philosophical views as positivism. However, if we cast a glance at his scientific practice, for example, at his theory of the biosphere, we find that some concepts implicit in his theory are not as evidently positivistic as his philosophy of science.

L. Kolakowski (1971, pp. 9-19) in the „*Die Philosophie des Positivismus*" distinguishes four important characteristics of positivism: phenomenalism, nominalism, the thesis on the unity of scientific method, and the prohibition of value statements. From this viewpoint, Vernadsky's philosophy of science and his scientific practice well correspond to the third and fourth characteristics. As we have seen, he insisted on the existence of a unified method, which is proper to all sciences. He also saw biospherical studies as an interdisciplinary domain, where all sciences could cooperate on the basis of the unified scientific principles. Vernadsky evidently tried to escape making value statements in his theory. The whole theory of the noosphere is an attempt to provide good geological and biogeochemical basis for social science. He tried to appeal to objective empirical geological and biogeochemical laws. One of his favourite terms, „lawful", reflects this intention.

The situation changes if we take into account the phenomenalism and nominalism of Vernadsky. In his philosophy of science, phenomenalism and nominalism are in keeping with the concept of empirical generalisation and the atomic view of inert and living natural bodies which is basic to biogeochemistry. However, constructing the „empirical" parts of his theoretical system, namely the theory of the biosphere and its evolution into the noosphere or the space-time theory, he transgresses the limits of these two rules of positivism. Phenomenalism is defined by stating that there is no real difference between „essence" and „phenomenon". Phenomenalism is followed by nominalism, which means the prohibition of any knowledge derived from general notions independent of the separate objects (natural bodies) being studied.

One of the classic examples of a positivistically unacceptable notion is the notion of matter (Kolakowski, 1971, p. 122), which is alien both to the phenomenalistic and the nominalistic approaches. The notion does not correspond to any real entity in the world.

Vernadsky's notion of living matter can also be interpreted as positivistically unacceptable. One never observes living matter but only natural bodies spatially separated from one another, closed living systems - organisms. There are no properties of living matter which would not be properties of living organisms. Thus, the notion of living matter breaks simultaneously both rules of positivism: phenomenalism and nominalism.

However, if we will have a look at this notion from the viewpoint of those aims which Vernadsky had in mind when elaborating this notion, we find that it appears more positivistic again. Vernadsky introduced the notion „living matter" to escape the concept of „life" closely connected with philosophy and religion. The notion „living matter" reflects the viewpoint of a new science created by Vernadsky - biogeochemistry. The biogeochemist is interested, according to Vernadsky, in the qualitative chemical, atomic analysis of living matter (Lapo & Smyslov, 1989, p. 110) and sees the living organism as a chemical substance, as a totality of atoms. This viewpoint, reducing living systems to the atomic level, can be seen as quite nominalistic. At any rate the concept of living matter is said to be more positivistic than the vague concept of life.

The concept of the biosphere, which is basic to Vernadsky's whole theoretical system, causes more difficulties in regard to positivism. The biosphere as a self-regulating system cannot be directly observed. Also it cannot be directly derived from any biogeochemical data. The important evidences of this self-regulating system such as the ozone layer, the organogenic rocks, the biogenic and stable atmosphere and so on, do not make the biosphere observable. They only help to build some arguments in favour of the existence of the biosphere. The notion of the biosphere cannot be directly derived from any empirical generalisation or observation and, thus, can be seen as a departure from the pure phenomenalistic approach.

The same can be said about the noosphere concept of Vernadsky (see 2.3.10.). Even if we accept Vernadsky's arguments, it would nevertheless be a purely theoretical prediction far from a phenomenalistic „empirical generalisation". In his summarising work *„On the States of Space in the Geological Phenomena*" (1980) Vernadsky (1980, p. 111) formulates the „basic empirical generalisation" which lays the foundation for the biosphere-noosphere theory: „The logic of natural science is closely tied up in its foundations with the geological envelope where human reason appears...". It is easy to see that this „generalisation" is metaphysical rather than empirical and appears to be alien to classical positivism.

These examples show that talking about the positivism of Vernadsky, we should clearly differentiate between his theory of science and his real scientific, theoretical practice.

2.3. *VERNADSKY's THEORY OF THE BIOSPHERE AND ITS TRANSITION INTO THE NOOSPHERE*

2.3.1. *The Origin of the Term*

It is difficult to identify the thinker, who for the first time expressed the idea that the processes in living and non-living nature are intimately connected. The idea has appeared from time to time since the 17th century.

One of the earliest and clearest expressions of the idea is found in the works of Georges-Louis Buffon (1707-1788). He coined one of the central terms in the theory of the biosphere - 'living matter' (1749) and posed the question about the general quantity of living matter in the Earth. Buffon understood the leading role of living matter in the Earth processes and pointed out that living matter can produce non-living matter as well as use non-living matter to produce living structures (Buffon, 1984).

A further step in the development of the concept of the biosphere was made by Buffon's pupil Jaen-Baptiste Lamarck (1744-1829). Lamarck considered the nature as a whole, emphasising the close interconnections of abiotic and biotic compounds (Ghilarov, 1998; Ghilarov, 1999). He declared that all natural inorganic elements can be found in living organisms and realised that an explanation for this was necessary. In order to solve this problem, Lamarck assumed that animals and plants perform a decisive role in the forming of the Earth's crust. In his *Hydrogeology* (1802), Lamarck already proposed that the production of most minerals in the Earth's crust is tied up with the processes of life. In this work he also proposed the term 'biology' which Lamarck considered as a part of the 'physics of the Earth' (*physique terrestre*). Lamarck formulated the fundamental objective of what he called 'physics of the Earth' and what we call now *biospherology* or *geophysiology*: „A sound physics of the Earth should include all the primary considerations of the Earth's atmosphere, of the characteristics and continual changes of the Earth's external crust, and finally of the origin and development of living organisms" (transl. by: Grinevald, 1996, p. 35). He understood that living organisms played a major role in the history of the Earth and made a step toward a holistic view of the Earth. At the same time, he did not present this group of thoughts as a conception and did not give a name to the phenomenon he discovered.

At approximately the same time, we find some attempts to give a proper name to the early geophysiological speculations. Alexander von Humboldt (1769-1859) coined the term '*Die Lebenssphaere*' for describing the sphere, where atmospheric and geological processes are coupled with life processes. A little later, a German zoologist and geographer, Friedrich Ratzel (1844-1904), proposed the term '*Der Lebensraum*'.

Thus the idea that there is an envelope surrounding the Earth which is characterised by the presence of life was spread since works of Buffon and Lamarck. Nevertheless, the different terms proposed for the description of the phenomenon were not widely accepted.

At those times the term 'biosphere' already existed. It is known that early in the nineteenth century the 'Zellinhaltskoerper', discovered with the help of the microscope, were often understood in the light of Leibniz' monadology and were seen as the bearers of the life functions. These 'monads' were named '*the biospheres*' by A.F.T. Mayer (1837) (Jahn, 1982, p. 361).

In modern science the term '*biosphere*' is usually credited to Eduard Suess (1875, p. 159; 1909, pp. 739-740), who was a professor of palaeontology and geology at the University of Vienna. The term biosphere was used by Suess in passing and, as it represented in his works, can be interpreted in the two ways: (1) as the sum total of living organisms and (2) as a geosphere which is created and organised by the processes of life.

These two meanings of the term have been widely spread in the 20th century. Plausibly, the most famous user of the term 'biosphere' in the first sense was P. Teilhard de Chardin (1881-1955), who created an original concept of the biosphere-noosphere evolution. This use of the term can also be sometimes found in current scientific literature (Monod, 1971; KEL, 1978).

Perhaps the first Russian scientist to use the term 'biosphere' was E. J. Petry (1854-1899). He used the expression in 1882 and understood it as the totality of all organisms. His pupil D. Koropchevsky (1842-1903) gave the first definition of the biosphere (in Russia) as a 'living cover' of the Earth based on the works of F. Ratzel and G. Wagner (1840-1923) (Vassoevich, Ivanov, 1977, p. 64).

The detailed theory of the biosphere was elaborated by V.I. Vernadsky (1863-1945), who had a personal acquaintance with Suess. Vernadsky gave the term of Suess a quantitative meaning and elaborated a biosphere-noosphere theory, where the biosphere appears as a self-regulating system and geological envelope. As George E. Hutchinson (1970) stated: „It is essentially Vernadsky's concept of the biosphere, developed about 50 years after Suess wrote, that we accept today".

Paradoxically Vernadsky's original concept of the biosphere is not actually known in the West. Some of his important works became only recently available in English and German (Vernadsky, 1997; Vernadsky, 1997[1]; Vernadsky, 1998). His main work, „*The Chemical Structure of the Earth and its Environment*", which he called „the book of my life", has not yet been translated into German or English. In Russia, the scientific heritage of Vernadsky is well known. But even today, more then 50 years after Vernadsky's death, his scientific heritage is actively discussed. New interpretations of the important aspects of his biosphere theory continue to appear.

2.3.2. *The biosphere as a geological envelope*

In the theoretical system of Vernadsky, the concept of the biosphere is required by the new branch of science created by him: *biogeochemistry*. Vernadsky began the „synthetic" biogeochemical works in 1916, but coined the term 'biogeochemisrty' and formulated the basic tasks of this new science only in 1923 (Lapo & Smyslov, 1989, p. 56). Biogeochemistry studies the geological manifestations of life and considers biochemical processes in living organisms in relation to their impact on the geosphere (Vernadsky, 1997, p. 156):

> „The competence of biogeochemistry is defined, on the one hand, by the geological manifestations of life taking place under this aspect, and on the other, by the internal biochemical processes in the organisms - the living population of our planet. In both cases (for biogeochemistry is a part of geochemistry) one may identify as study objects not only chemical elements, i.e. the usual mixtures of isotopes, but also various isotopes of one and the same chemical element".

Neither living organisms by themselves nor their environment abstracted from them are the specific objects of biogeochemistry. A biogeochemist is interested, first of all, in studying the cyclic processes of the atomic exchange between living organisms and their environment. The latter can only be described on the basis of a detailed study of the interrelations of living and inert matter in the space-time of Earth and throughout the Earth's history. How can the main subject of biogeochemical research be defined? It is not the organism (genus, species). It is not even the sum total of living organisms (biota) or the inert environment. The interaction between the environment and living matter is the characteristic research subject of biogeochemistry. Biogeochemistry never aims at the organism level or at the environmental level separately. It concentrates, in the sense of Vernadsky, on the biologically controlled flow of atoms, *which takes place in a specific geological domain*.

In order to define the research field of this newly created science, Vernadsky introduced his interpretation of the term the *biosphere*. He had used the term 'biosphere' since 1911, but first gave a clear definition in 1923, after the beginning of his synthetical works in biogeochemistry (Vassoevich, Ivanov, 1977, p. 69, Vernadsky, 1923, pp. 38-39). The biosphere of the Earth appears as one of the geospheres occupied and organised by life and thus can be seen as a geological envelope.

Being a geological envelope, the biosphere can be structured geologically (Vernadsky, 1991, p. 120):

> „The biosphere appears in biogeochemistry as a peculiar envelope of the Earth clearly distinct from the other envelopes of our planet. The biosphere consists of some concentric contiguous formations surrounding the whole Earth and called geospheres. The biosphere has possessed this perfectly definite structure for billions of years. This structure is tied up with the active participation of life, is conditioned by life to a significant degree and is primarily characterised by dynamically mobile, stable, geologically durable equilibria which, in distinction from mechanical structures are quantitatively fluctuating within certain limits in relation to both space and time".

Vernadsky (1965, pp. 107-108) talks about the following geospheres[10]: the troposphere, the hydrosphere, the land surface and the sphere of the subterranean life.

In connection with this geological interpretation of the biosphere, Vernadsky posed a question on its spatial limits. Some researchers note that the different Vernadsky definitions of the limits of the biosphere are not in conformity with each other (Kolchinsky, 1990; Gegamjan, 1980). Accepting this criticism in principle, I nevertheless attempt to reconstruct the views of Vernadsky on the subject systematically.

The apparent contradictions between Vernadsky's estimates of the limits of the biosphere are tied up with: (1) differing empirical data which Vernadsky had at his disposal in the various periods of his creativity; (2) the usage of differing ruling principles for the limits of the biosphere. One can abstract from the texts of Vernadsky two basic principles.

First principle: the limits of the biosphere are defined by the presence of life. The impossibility of life manifestations indicates the limits of the biosphere. At first consideration, the principle seems to be clear. However, this statement represents a necessary, but not a sufficient condition. The notion *presence of life* needs more precise definition. Separate organisms can often be found outside of the average limits of the biosphere. Does this mean that the biosphere is represented everywhere, where separate organisms can be identified? To answer this question Vernadsky (1994, p. 372) introduced the term *field of life stability*, which exceeds the field of the biosphere. Field

[10] Vernadsky's use of the term 'geosphere' differes from most of its contemporary meanings. According to the *Glossary of Geology* (1982), 'geosphere' means: (a) = lithosphere, (b) the lithosphere, hydrosphere and atmosphere combined, (c) any of so-called layers or spheres of the Earth.

of life stability, in turn, differs from *field of life existence*, which is defined as a field of prolonged life existence connected with the multiplication of organisms. The limits of the biosphere are restricted by the field of life existence (Lapo, 1987, pp. 49-50, 56). The disparity between the field of life existence and the field of life stability is explained by the vertical and horizontal expansion of the biosphere over geological time (Vernadsky, 1994, p. 365).

The second principle for defining the limits of the biosphere is phrased by Vernadsky (1965, p. 79) as follows:

> „The primary identifying characteristic of the biosphere is the activity of living matter in all its processes. Hence, a substrate in which living matter exists can belong to different geological envelopes. In spite of this fact, a substrate involved in the processes of living matter is separated from its own envelope and should be classified as a substance of the biosphere. We can observe this phenomenon in the biosphere for the following envelopes: the stratisphere, the lower and the upper metamorphic envelopes and for the granite envelope".

The second principle supplements the first characterising the biosphere also as a dynamic system. But it defines this system from another viewpoint. The first principle shows the dynamics of living matter. In the second case, Vernadsky talks about the biologically controlled dynamics of the inert parts of the biosphere.

The dynamics of inert matter, in this case, are manifested in the following processes: „inert matter of the Earth is dislocated over geological time towards the centre of the Earth and back from the centre to the Earth's surface" (Vernadsky, 1965, p. 75). The dislocation of substance of the geological envelopes does not make it possible to include or exclude them from the biosphere categorically [*eindeutig*]. For example, we cannot say that the whole stratisphere belongs to the biosphere, but we can say that the matter of the stratisphere can be involved in biogeochemical processes and, accordingly, can be classified as a part of the biosphere. The same approach can be applied to the interpretation of the contradictory statements of Vernadsky about the granite envelope of the Earth. Compare: "the granite envelope is an area of bygone biospheres" (Vernadsky, 1965, p. 325) and „the granite masses belong to and are found in the biosphere" (Vernadsky, 1965, p. 131). These apparently contradictory statements should be understood as follows: the granite envelope of the Earth being a product of former activity of living matter is, in general, the area of bygone biospheres. And, hence, can be identified as a part of the framework of the biosphere; however, where masses of granite are involved in the actual life activity (such as the bioinert weathering processes in regions where the granite masses are close to the surface of the Earth, as in Scandinavia) they must be classified as matter of the biosphere.

After this look downward, some words about the Earth's atmosphere should be added. It is clear that, according to the second principle, the atmosphere of our planet belongs to the biosphere. Vernadsky (1965, pp. 122, 126) described the troposphere as the biogenic gaseous component of the biosphere, which consists of three parts: the overhead troposphere, the subterranean troposphere and the submarine troposphere. At the same time the biosphere cannot exceed the limits of the field of life existence or as a minimum the field of life stability. This means that there is a conditional atmospheric border of the biosphere in the atmosphere. There are some references in Vernadsky's works (1965, pp. 122, 125, 126) which show that this border occurs at the height of the low layers of the stratosphere; but even the stratosphere can be involved in the biosphere due to human activity. It should be stressed that in the vocabulary of Vernadsky, '*biogenic*' does not necessary mean '*belonging to the actual biosphere*'.

The concepts of the two fields of life introduced by Vernadsky as well as his concept of bygone biospheres show the necessity of a more complex classification of the biospheric environment. Vernadsky did not clearly define a place for the biosphere between other geological envelopes, which had, therefore, to be elaborated further. A scheme of the relationship between the biosphere and other geospheres as accepted by most of the followers of Vernadskian tradition (Kolchinskij, 1990, p. 10, Lapo, 1987[1], p. 59-60) was proposed by N. Vassoyevich and A. Ivanov (1977, pp. 72-75).

The part of the atmosphere above the biosphere (determined by the field of the presence of life) is defined as an *apobiosphere* (ABS). The ABS is subdivided into two subspheres: ABS_1 (= parabiosphere of G. E. Hutchinson) is a sphere below the ozone layer corresponding to the field of life stability; ABS_2 is the abiotic part of the atmosphere. Below the biosphere one finds the so-called *metabiosphere* or the area of the *bygone biospheres*, which occupies the metamorphic and granite envelopes (11-60 km). All these spheres, together with the biosphere, are called the *megabiosphere*, which is defined as an area directly and indirectly influenced by living matter, including all products of life activity and all bygone biospheres.

2.3.3. *The Biosphere as a Self-regulating System*

Examining living matter from the geochemical viewpoint, Vernadsky (1994[t]) arrived at the conclusion that the chemical compounds of the different species do not reflect that of their environment, but, on the contrary, living matter has determined the geochemical history of almost all the elements of the Earth's crust in the process of making the environment favourable to itself. Thus, living matter shapes the biosphere into a self-regulating system. The biosphere being seen as a self-regulating system embraces both the totality of living organisms (living matter) and their environment to the extent it is involved in the actual processes of life, that is, including the troposphere, the ocean, and the upper envelopes of the Earth crust, possibly down to the mantle.

Living matter is an active part of the biosphere and influences all geospheres. It determines the structure and the regularities of the biosphere. The structure of the biosphere is expressed by the totality of dynamic equilibria which keep the biosphere in a steady state. This structure Vernadsky calls *организованность*, which can be translated into English as *organisation*. Vernadsky (1965, p. 236) coined this term in order to distinguish his model from the theoretical constructions of *mechanism*, i.e. mechanistic views of organisms and the world. He emphasised that his understanding of organisation is close to that of the English philosopher and mathematician A. Whitehead (Vernadsky, 1965, p. 52). Organisation differs from *mechanism*, because in organisation, the parts of the whole are determined but not fully determined by the whole. At the same time, the concept 'organisation' also differs from the concept of 'organism', because in organisation two kinds of matter (living and inert) and, correspondingly, two kinds of regularities interact. The structure of the biosphere is described as a dynamic equilibrium: „No single point of this system is fixed during the course of geological time. All points oscillate around some centre" (Vernadsky, 1997, pp. 225-227).

An example of such dynamic equilibrium is the troposphere. The gases of the troposphere are mostly biogenic. Vernadsky was of the opinion that this generalisation had been anticipated by Boussingault (1802-1887) and Dumas (1800-1884). The dynamic equilibrium of, for example, oxygen shows that living matter is essential to the maintenance of an optimal concentration of oxygen in the troposphere. This inference can be generalised to the all basic gases of the atmosphere (Vernadsky, 1965, p. 238):

> „All basic gases of the troposphere and of the higher gaseous envelopes - N_2, O_2, CO_2, H_2S, CH_4, etc., - are produced and quantitatively balanced by the total activity of living matter. Their sum total is quantitatively invariable over geological time...". Vernadsky infers that „life, i.e. living matter creates the troposphere and constantly maintains it in a specific dynamic equilibrium".

Thus the relationship between living matter and the troposphere can be expressed in the following scheme:

LIVING MATTER ⇔ THE TROPOSPHERE

This geologically perpetual form of dynamic equilibrium is an example of the natural organisation of our planet (Vernadsky, 1965, p.230).

It can be remarked here, that the 1-st Gaian principle of atmospheric regulation (Lovelock, Margulis, 1974) actually was derived by Vernadsky on the basis of his biogeochemical research 50 years before Lovelock (Levit & Krumbein, 1999).

The same model can be constructed for the water envelope or hydrosphere of the planet, for the soils and for the general geochemical environment: „Every organism is a centre of free energy. In its totality, living matter transforms completely the domain of life - the biosphere" (Vernadsky, 1965, p. 232) and „determines all the basic chemical regularities of the biosphere" (Vernadsky, 1965, p. 241). Thus, the biosphere is a self-regulating system, which transforms the environment not chaotically, but in accordance with established regularities, which respond to the needs of terrestrial life.

2.3.4. *Substances of the Biosphere*

In the works of Vernadsky, we can find three ways of classifying biospherical matter. The most general classification implies three kinds of matter: living, inert and bioinert (Vernadsky, 1965, p. 231). The basic division, however, is the division into inert and living matter.

Living matter of the biosphere is the sum total of living organisms actually existing in it. Living matter has its own structure (*organisation*) and can be seen as a function of the biosphere (Vernadsky, 1991, p. 15). It is dispersed in the form of living organisms and sharply separated from its inert environment (Vernadsky, 1965, p. 128). This kind of matter plays the main role in the biosphere, being the most powerful geological force on Earth.

The second kind of biospherical matter is *inert matter*, i.e. „a kind of matter produced without the participation of living matter" (Vernadsky, 1965, p. 59). Inert matter is the exact opposite of living matter. However, there is a perpetual material and energetic exchange between living and inert matter manifested in the biogenic flow of atoms.

Bioinert matter represents the third basic kind of matter of the biosphere. This is a substance „which is made by living organisms and inert processes simultaneously and represents the stable dynamic equilibria of both of them" (Vernadsky, 1965, 59). Vernadsky called this kind of equilibrium *complex dynamic equilibrium*. The bioinert natural bodies are of great importance in the biosphere. The forests, the fields, plankton, benthos, soils, marine silt and sediments, all terrestrial waters, etc, are examples of the bioinert natural bodies. When living organisms die, they also form bioinert bodies. The rotting of a macroscopic organism (biocenoses) is accompanied by an extremely powerful biogenic migration of atoms and represents a kind of symbiosis of micro- and macro- organisms. The process of rotting represents, according to Vernadsky (1965, pp. 265, 268) the *second biochemical function of living matter* in contrast to the *first biochemical function* connected with the life cycle of the organism (breathing, eating, multiplication).

It is also important to note, that bioinert matter is not a kind of intermediate stage between living and inert matter. There is an impassable boundary between living and inert matter.

The next kind of classification, which can be found in the works of Vernadsky is caused by the insufficient character of his tripartite classification (living, bioinert, inert). There is a kind of matter which cannot be classified as living or bioinert, but which nevertheless keeps an imprint of life. This kind of matter Vernadsky (1965, p. 127) calls *biogenic*: „The stuff of the biosphere is sharply and deeply dissimilar: living, inert, biogenic and bioinert matter".

The above described system of classifying matter seems to be the most consistent one. But Vernadsky proposed one more system of classification which is worked out in more detail:

1) living matter
2) biogenic matter
3) inert matter
4) bioinert matter
5) radioactive materials
6) separated atoms (isotopes)
7) matter of cosmic origin.

The latter system of classification has obvious shortcomings because of its inconsistency (Kamshilov, 1979; Kolchinsky, 1990). There are no universal criteria of classification in it. Matter in (1 - 4) is classified in accordance with its relation to living matter. Radioactive isotopes (5) can be involved in the processes of both living and inert matter. Isotopes can be radioactive and at the same time of cosmic origin (7). Besides, according to Vernadsky, the biosphere constantly absorbs some cosmic matter entering from outer space and emits some matter into space. It is sufficient in this account to call *cosmic matter* that matter which is of cosmic origin and was not absorbed by the biosphere at the present moment. But this kind of matter cannot be treated as really biospherical.

2.3.5. *Living and Inert Matter*

The opposition *living-inert* takes a very important place in Vernadsky's concept. Every significant theoretical statement of his theory is connected with this juxtaposition: (1) the Pasteur-Curie principle, (2) the Redi principle, (3) the dissymmetry concept, (4) the three biogeochemical principles and (5) the statement about the impossibility of abiogenesis.

In the work „*Scientific Thought as a Planetary Phenomenon*" (1991), Vernadsky summarises the differences between living and inert matter in a table. I present the main statements of this classification.

Inert matter	*Living matter*
I. Inert matter is dispersed only to the extent it is connected with living matter, i.e. with the biosphere.	Living matter exists only in the dispersed form, i.e. in the form of living organisms, autarchic centres of energetic and physical-chemical processes (Vernadsky, 1965, 128).
II. Inert natural bodies obey the symmetry laws.	The solid substance of living organisms (including dispersed particles of the colloid mediums) obey the dissymmetry laws.
III. A new inert body is created by physical-chemical, geological or biological processes, without any reference to the earlier natural bodies.	A living natural body can only be begotten by another living natural body.
IV. The processes creating an inert natural body are reversible in time.	The processes creating a living natural body are irreversible.
V. There is no multiplication among inert natural bodies. An inert natural body can be created by synthesis.	A living natural body is created by multiplication, a complex biochemical process. This process can go on only in a peculiar state of space.
VI. The number of inert natural bodies does not depend on the size of our planet.	The number of living natural bodies depends on the size of the Earth's envelope, the biosphere.
VII. The surface area and the volume of the manifestation of the inert natural bodies are not defined within the limits of the planet and their mass varies over geological time.	The mass of living matter fluctuates about a constant value over geological time. It depends on the quantity of solar energy absorbed by living matter.
VIII. The minimum size of inert natural bodies is determined by the dispersion of the matter-energy (atom, electron, etc.). The maximum size is determined by the size of the planet (bioinert natural body).	The minimum size of living natural bodies is determined by respiration, biogenic migration of gases etc. (Sniadetcki principle). The maximum size of a living natural body does not exceed hundreds of meters and may well depend upon some deep causes that define the limits of the existence of the states of space corresponding to a living natural body.
IX. The chemical composition of an inert natural body is a function of its environment.	Living natural bodies create their chemical compounds by themselves.
X. The number of chemical compounds (molecules and crystals) in inert natural bodies is limited.	The number of the chemical compounds of living natural bodies is theoretically unlimited.
XI. All natural processes among inert bodies decrease the free energy of the environment.	Living matter increases the free energy of the biosphere.
XII. Isotopic mixtures do not change in inert natural bodies of the biosphere.	The change of isotopic relations is perhaps a specific property of living matter.

It is easy to see that the table is a result of Vernadsky's work in the different branches of his scientific activity: biochemistry, biogeochemistry, space-time theory, geology, evolutionary theory. The inert-living dichotomy is tied up with the central aspects of Vernadsky's theoretical system. Most of them are discussed in the corresponding chapters of this dissertation. Here I comment only points (V) and (XII) of the table.

It is commonplace now to consider that multiplication (self-reproduction) is not proper only to animate systems. Erich Jantsch (1981, p. 3), the author of the self-organisation principle stated: „If metabolism, self-reproduction and the transfer of mutations were, until recently, assumed to be unique characteristics of life, they may now be shown to hold equally for precellular systems of molecules". In this connection it should be remarked, that in the theoretical world of Vernadsky, multiplication is seen not as a simple self-reproduction. Multiplication is a sequence of what Vernadsky calls the *Redi principle* (*omne vivum e vivo* - all living from living) and tied up with the impassable space-time border between living and inert matter. If we leave for a moment the question, whether multiplication in the inert world really exists, the problem can be formulated as follows: there are some ways to produce an inert object including multiplication, but there is only one way to produce an animate system, namely, multiplication. Self-reproduction of living matter cannot be interrupted for a moment and then continued again at one's own random choosing.

The second remark concerns the problem of the relationship between isotopes and living matter. Vernadsky devoted some special papers to this problem, but it is quite difficult to interpret unequivocally the ideas of Vernadsky about the relationship between living matter and the stable and radioactive isotopes. From our viewpoint, one can talk about two aspects of this problem in his works.

In the work written in 1926, „*Isotopes and living matter*", Vernadsky declared that „the atoms forming living matter...can differ from those in the environment", because:

- there is no abiogenesis in geological history;
- the chemical elements exist in living matter in a special form;
- there are much more homogenous chemical elements (i.e. consisting of the similar atoms) in living matter in comparison with the composition of the environment;
- of the sharply differing geochemical histories of the chemical elements of inert and living matter (Vernadsky, 1926).

Generally, Vernadsky expected that the space-time dissymmetry of living matter should somehow influence the distribution of isotopes in the animated nature.

At first, he thought that the situation with the isotopes would be analogous to the situation with the homochirality of biological macromolecules: he expected that all chemical elements of living matter would be 'pure' isotopes and not mixtures of isotopes. An organism has the possibility to choose between the diverse isotopes. In 1928 Vernadsky started experiments in order to prove this hypothesis. However both his own experiments and the experiments of other scientists did not give decisive results.

In the 1940's, Vernadsky already left the radical positions and reported that according to the results of his laboratory, it is possible to talk about the characteristic modification of isotopic mixtures in the processes of life and in inert processes under certain circumstances. He wrote that the experiments of his laboratory show that isotopic mixtures of chlorites and serpentines are modified by high temperature and pressure (increased quantity of O_{18}). Vernadsky (1965, p. 237) concluded: „in the life process of the biosphere, the same phenomenon is manifested which one can observe in the inert environment only at high temperature and pressure".

This allowed to E.M. Galimov to state that the direction of Vernadsky's thinking is close to some contemporary investigations in biogeochemistry. Galimov (1989, p. 343) points out the regular thermodynamic isotopic distribution in biological systems caused by the leading role of ferments in the chemical processes of living organism: „Actually, ferments organise the space in which the movement of biological matter takes place in a special way. Therefore it is possible to assume that the ideas and the notions of Vernadsky have been realised (albeit in slightly different terms and categories) in the contemporary theory of biological fractionation of isotopes". This shows again that Vernadsky approached isotopes according to his space-time theory.

To sum up: the table shows that there are living and inert natural bodies connected only by a biogenic flow of atoms and there are no transitional forms between living and inert matter. The table is a result of Vernadsky's work in the different fields of his theoretical system.

2.3.6. *The main principles on which the biosphere theory is based*

The biosphere is a stable dynamic equilibrium. Its main peculiarity is the presence of living matter within this geological envelope. Living matter transforms solar energy into free energy of the biosphere („the biosphere can be treated as the area of the Earth's crust occupied by the transformers"). Inert substances are an essential component of this process. Thus the basic principles of the biosphere theory should describe the relations between the main components: *living matter, inert matter and energy*.

1. *The principle of the quantitative invariability of life* is a direct consequence of the statement that the biosphere is a product and transmitter of solar energy. Vernadsky uses this principle in all his significant works. One of the earliest references to this principle can be found in the notation [„On the constancy of living matter"] (1908): „The quantity of living matter is constant during the whole period of geological history that can be explored" (Sytnik et all., 1988, p. 256).
   On the one hand, this statement seems to be paradoxical, if one takes into consideration the complex processes of multiplication as well as vertical and horizontal expansion of the biosphere. On the other hand, if the life energy, in fact, is transformed solar energy, then it is logical to say that life should be constant as far as its quantity is concerned. In the case of a permanent increase of life quantity we should expect the existence of other trivial energy sources.[11] Vernadsky did not know in this connection about two facts. First, some researchers point out that during the 3,5 aeons of life existence, the sun's output of energy has increased by at least 30 per cent (Lovelock, 1987, p. 19). Second, it is known at present that living matter can use some endogenic terrestrial energy. The second discovery does not destroy Vernadsky's hypotheses in principle, because of the limited character of endogenic energy sources. About the increasing output of solar energy, it should be said, that it was assumed by Vernadsky that living matter transforms the optimal quantity of solar energy. On the other hand, the thesis of the constancy of living matter was not a dogma for Vernadsky and could be corrected on the basis of new data and biogeochemical principles.
2. The biogeochemical principles (BGCP's) portray the general picture of energy flow in the biosphere. I present these principles in two variants, as they were forwarded by Vernadsky in his various works.[12]

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[11] The same way of thinking was presented by Krumbein (1983) without knowing Vernadsky's arguments.

[12] The first and the second principles were presented by Vernadsky, for the first time, in 1928 in the report „*The Evolution of Species and Living Matter*" (Aksionov, 1994, p. 375). Vernadsky formulated his BGCP's evidently influenced by A. Lotka's *Elements of Physical Biology* (1925), however, Vernadsky did not mention Lotka in this respect.

First BGCP:

a) „Geochemical biogenic energy tends towards a maximum in the biosphere" (Vernadsky, 1993[1], p. 372).

b) „Biogenic migration of the atoms of chemical elements tends towards a maximum in the biosphere" (Vernadsky, 1965, p. 283).

Second BGCP:

a) „Organisms survive in evolution only if they increase biogenic geochemical energy" (Vernadsky, 1993[1], p. 372).

b) „The evolution of species (over geological time), tends toward the creation of stable life forms in the biosphere and moves in the direction of increasing biogenic migration of the atoms" (Vernadsky, 1965, p. 270).

The *third BGCP* can be treated as a logical consequence of the first two principles. It declares that over geological time, since the Cryptozoic era, the population of our planet must have attained the maximum possible value (Vernadsky, 1965, p. 286).

Some remarks should be made in connection with the BGCP's.

If one considers the second biogeochemical principle only from its quantitative aspect, then it, plausibly, needs some amendments. Thus Kolchinsky (1990, p. 116) based on the works of W. Krumbein (Krumbein, 1978), concludes the following:

> „W. Krumbein showed that in the products of activity of microorganisms, the concentration of manganese is 1,200, 000, of iron is 650, 000, of silver is 24,000, of vanadium is 420, 000 times more than in their environment. Evidently there are no other groups of organisms (including plants, fungi, or animals) which are capable of concentrating these elements so intensively. In this connection, we should apply the second biogeochemical principle only in the boundaries of kingdoms".

This conclusion seems to be legitimate, if we contrast microorganisms (bacteria and fungi) to macroorganisms, instead of contrasting microorganisms to fungi, plants and animals. Vernadsky was aware of the difference between the biogeochemical power of microorganisms (bacteria, fungi) and macroorganisms (Vernadsky, 1965, pp. 267-268) and that is the very reason why he contrasted the biogenic migration of the first to the biogenic migration of the second kind.

It should also be remarked that other attempts were made in contemporary scientific literature to describe the directedness of biospheric evolution in terms close to Vernadsky's terminology but ignorant of Vernadsky. For example, F. D. Por (1980, pp.397-398) states: „Evolution of the global ecosystem towards a state of climax, with rapid and optimal recycling of all the bioproducts, is the basic orthogenetic motor of animal progress". Nevertheless, the advantages of the radical Vernadsky definitions are evident: they are more general and precise. They allow placing the problem in the context of the Earth's crust and taking into consideration all biogeochemical cycles and crucial elements, not only the 'recycling of the bioproducts'.

It seems that the three biogeochemical principles contradict the principle of constancy of life. But they, plausibly, do not, if we assume that the maximum of biogeochemical energy is a quantitatively definable value limited by the intensity of solar radiation and quantity of chemical elements involved in the life cycles. If so, then evolution, where the first and the second kinds of biogenic migration dominate and the intensity of solar radiation is stable, must have a natural temporal limit. That means that species, whose activity are connected mostly with the third kind of biogenic migration of atoms –

which simultaneously are capable of using accumulated forms of energy, should be expected in the biosphere. The human species meets these prerequisites.

2.3.7. *The evolution of the biosphere*

The ideas of Vernadsky about the evolution of the biosphere originate from the biogeochemical investigations which he started in 1916. As early as 1917-1918, Vernadsky intensively elaborated his concept of living matter from the biogeochemical viewpoint. At this time, he had not yet coined the term 'biogeochemistry' and did not even give a definition of the biosphere. Nevertheless, he seemed to clearly realise the significance of his ideas for the evolutionary theory. In his diaries in the beginning of the 1920s, Vernadsky compares himself with Ch. Darwin and remarks that his concept of living matter should present another aspect of the evolutionary theory (Sytnik et. al., 1988, p. 88). One of the assistants of Vernadsky in the early period of the biogeochemical works, Th. Dobzhansky (1900-1975) (Vernadsky, 1998, p. 165; Vernadsky, 1994², p. 253), became later one of the founders of the „evolutionary synthesis" (Mayr, 1982, p. 119) and highly regarded the work of Vernadsky.

While investigating living matter, Vernadsky conducted work in the following basic directions: (1) the quantitative composition of elements in certain groups of organisms; (2) studying the (bio-) geochemical history of the chemical elements; (3) measurements of geochemical energy in different species.

Based on the results of his experimental work, Vernadsky concluded already in the beginning of the 1920s that his concept of living matter would influence the evolutionary theory. Studying the natural history of the chemical elements, Vernadsky (1994, pp. 66-68) comes to the conclusion that living matter constantly changes the environment and that there are no areas of the Earth's crust, ocean and the atmosphere, where one cannot find the manifestations of life [lectures of 1921]. Living matter, in its turn, is determined by the "general laws of combination and spreading of atoms" and by the peculiar geochemical factors (Vernadsky, Vinogradov, 1931, p. 149). A species, according to A. Vinogradov, turns out to be a morphological system multiplied by a geochemical determinant (Kolchinsky, 1989, p. 65). Projecting the idea of the co-evolution of a species and its environment on a biospheric scale, Vernadsky hypothesises that the whole external envelope of the Earth is subject to evolution. It is noteworthy that already in his diaries of 1919, Vernadsky questions the legitimacy of the analogy between the notions 'biosphere' and 'organism'. In 1919, he answered this question in the negative defining the planet as a mechanism and not as an organism. (Vernadsky, 1994², pp. 128-129). Later Vernadsky changes his mind and appeals to the notion 'organisation' in order to distinguish the biosphere both from mechanism and from "trivial" organism.

In his late works, Vernadsky assumes that the biosphere is a self-regulating system having its own evolutionary "interests". A leading force of the evolution of the biosphere is living matter, which has its own process of evolution partially independent from the needs of adaptation. Vernadsky (1991, p. 19) proposed that *living matter has its own evolutionary process independent from the changes of the environment.*

The biosphere as a whole behaves as if it has a peculiar evolutionary strategy: „We can and must talk about the evolutionary process of the biosphere by itself" (Vernadsky, 1991, p. 20; 1997, p. 30). The evolution of the biosphere is determined by the three BGCP's stated above. According to the BGCP's, evolution goes in the direction of increasing the level of self-regulation and stability. One of the basic methods of realisation of these „interests" of the biosphere is to increase the intensity and complexity of the biogenic migration of atoms. Evolution that satisfies these 'interests' turns out to be a multi-stage process and when it exhausts one method, it rises to a higher stage. Roughly schematising, one talks about the phase of biochemical evolution (microorganisms) which was replaced by the stage of mainly morphological evolution, which, in turn, was replaced by a kind of evolution, the main manifestation of which is a cephalization process. As E. Kolchinsky (1990, p. 38) puts it: „Cephalization is for Vernadsky a consequence of evolution in the situation of increasing complexity of interactions between the organisms when the potentials of the biochemical and morphological evolution were exhausted".

The increase of the dimensions of an organism was, at a certain stage, a powerful instrument for intensifying the biogenic migration of atoms without increasing the total biomass (quantity of living matter). The process of cephalization led towards more complex behaviour of organisms and hence, in turn, to an increase of the biogenic migration of atoms. It is clear from this scheme that the cephalizational stage of evolution also must have its limits.

Vernadsky himself defines the statement on the directedness of evolution as an empirical generalisation. The directedness of evolution is expressed by a polar time vector and, hence, evolution is an irreversible process. The directedness of evolution, according to the second biogeochemical principle, is expressed by the alteration of the character of the biogenic migration of atoms: „According to the second biogeochemical principle, the evolution of a species must move in a certain direction, namely, in the direction of increasing the biogenic migration of atoms. That means that evolution must have a directionality" (Vernadsky, 1965, p. 272). The second biogeochemical principle is a geochemical version of Darwin's principle of natural selection. It connects the evolution of species and the evolution of the biosphere: „The evolution of species turns into the evolution of the biosphere" (Vernadsky, 1997, p. 30).

Vernadsky emphasised that he approaches the principle of struggle for existence statistically. Thus, on this level, the directedness of evolution is seen by Vernadsky statistically. Kolchinsky (1989, p. 66) remarks that Vernadsky was alien to the conceptions of a strictly (pre-)determined evolution. At the same time, a statistical approach does not exhaust Vernadsky's notion of directedness. Vernadsky (1991, pp. 24, 53) clearly connects the directedness of evolution with the peculiar spatial-temporal features of living matter, i.e. with dissymmetry (for details see 2.1.). The spatial-temporal peculiarity of living matter guarantees the irreversibility of the evolutionary process. Vernadsky also wrote many times about the *lawful* character of the evolution of the biosphere. It was important for Vernadsky (1997, p. 31) to show that the transition of the biosphere into the noosphere (see below) is a lawful process which has will develop from the whole history of the biosphere:

> „When man is guided by a scientific (and neither a philosophical, nor a religious) concept of world, he ought to understand that *he is not an incidental, independent, from the surrounding world* - the biosphere or the noosphere - freely acting natural phenomenon. He is the inevitable manifestation of a great natural process having lasted in a regular way for at least two billions of years".

Vernadsky's viewpoint on evolution is close to what F. Ayala calls *indeterminate natural teleology*. As Ayala puts it: „Indeterminate or nonspecific teleology occurs when the end-state served is not specifically predetermined, but rather is the result of selection of one from among several available alternatives" (Dobzhanky et. al., 1977, p.

500). Indeterminate teleology results from a mixture of stochastic and deterministic events. Vernadsky (1997, p. 55) wrote that „the biosphere will transform (in one way or another, sooner or later) into the noosphere“. That is the way the noosphere created and the final form of the noosphere is not predetermined. The only thing which is determined is the direction of the evolution of the biosphere. The biosphere evolves in the direction of increasing stability, increasing degree of self-regulation and ultimately transforms into the noosphere.

Vernadsky also posed questions about specific aspects of the biospheric evolution. One of these issues is the problem of the evolution of the biogeochemical functions, which was analysed in detail by E. Kolchinsky (1990). In keeping with our objectives, I discuss only some general issues here.

A biogeochemical function is, according to Vernadsky, a role which a taxon performs in the biospheric cycling of matter. The most generalised list of biogeochemical functions includes five groups: 1) the gas function, regulating the gas-structure of the atmosphere including submarine and subterranean gas conditions; 2) the concentration function; 3) the oxidation-reduction functions; 4) the biochemical functions of organisms generating biogenic migrations of atoms connected with feeding, breathing, multiplication and destruction of organisms; 5) the biogeochemical functions of mankind (Vernadsky, 1965, p. 237). All „natural“ functions of the biosphere (1-4) can be fulfilled by morphologically different unicellular organisms (Vernadsky, 1994, p. 459).

Some species are chemically and morphologically relatively immutable (persistents, e. g., *Lingula*) and induce a *biogenic migration of the first degree* in accordance with the first BGCP. This is a kind of stable background in the picture of atomic migration. The *second degree of biogenic migration* is induced by evolving kinds of living organisms (Vernadsky, 1965, p. 285). This second kind of migration process is subject to evolution.

Vernadsky's classification of biogenic migrations is an evident and illustrative example of the evolution of biogeochemical functions. Vernadsky classifies biogenic migrations (1965, p. 267) into three kinds.

Biogenic migration of the first kind is a high-speed migration of atoms caused by unicellular organisms. Microbes and fungi produce such a powerful migration of atoms „that it seems to be incomparable with biogenic migration of atoms of the second kind“ (Vernadsky, 1965, p. 268).

The relatively slow biogenic migration of atoms caused by the multiplication and growth of the multicellular organisms is defined as *the biogenic migration of the second kind*. It should be remarked that it is more terminologically correct from the viewpoint of contemporary science to oppose, in this context, microorganisms - macroorganisms and not unicellular - multicellular organisms.

At first glance, it seems that the predominance of biogenic migration of the first kind over the second kind contradicts the second biogeochemical principle. But there is no contradiction here. One should take into account that the term *increasing*, which Vernadsky used to formulate this principle, can signify both intensification of migration and complication of the pathways of atomic migration.

Vernadsky further described a biogenic migration of atoms caused by the external activity of living organisms. This is *the biogenic migration of the third kind*. Examples of this kind of migration are: digging and burrowing organisms, birds, termites and the technological activity of mankind (Vernadsky, 1965, pp. 267, 277).

Biogenic migration of the first kind was the most powerful kind of atomic migration in the biosphere until the migration caused by human reason occurred. Nevertheless every kind of migration mentioned made the whole picture of biogenic migration more complex and intense and hence led to a more stable state of the biosphere and improved its adaptive capacities. This is also an important example of the evolution of a biogeochemical function because these three kinds of biogenic migration also reflect the different stages of biospheric evolution. The first kind of biogenic migration corresponds to the earliest stage of the evolution of the biosphere. The third kind of biogenic migration started to play a dominant role in the biosphere only with the appearance of *Homo Faber*.

The example is also illustrative in that it shows that Vernadsky's concept of the evolution of biogeochemical functions serves to describe the main stream of biospheric evolution: transformation of the biosphere into the noosphere.

There are also some other examples of the evolution of biogeochemical functions in Vernadsky's works, but it is not our objective here to give a detailed analysis of this problem. The ideas of Vernadsky concerning the evolution of biogeochemical functions were further elaborated by his immediate followers (f.e.: Samoilov, 1929; Vinogradov, 1935; 1944). In light of these considerations, the claim of M. McMenamin that Vernadsky developed a Slavic version of *substantive uniformitarianism* (the theory that nothing on Earth really ever changes) (McMenamin, 1998, p. 40) seems unsubstantiated.

The problem of the origin of life is, for Vernadsky (1994, p. 457), elevated to the problem of the origin of the biosphere: „Talking about the appearance of life on our planet we are only talking about the appearance of the biosphere". Vernadsky's theory of the origin of the biosphere is not trivial even from a contemporary point of view. Let us consider some aspects of this hypothesis.

One of the most criticised statements of this concept is the total rejection of abiogenesis in the biosphere. Vernadsky was almost always of the opinion that abiogenesis is impossible. To accept abiogenesis was for Vernadsky to destroy his whole theoretical system, for example, his space-time theory. In his latest works, he wrote: „there is no abiogenesis in the biosphere" (Vernadsky, 1991, p. 176); „there are no traces of abiogenesis" (Vernadsky, 1965, p. 59; 1980, p. 122).

As a rule, Vernadsky accompanies his statements of the impossibility of abiogenesis with his favourite ending „over geological time". Geological time coincides in Vernadsky's conception with the time of the biosphere existence. That means that he takes the problem, which was insoluble in the framework of contemporary science at his time, out of the brackets of the history of our planet. In relation to the problem of the origin of life, this approach means the following: there are no empirical grounds to solve the problem of abiogenesis today, but we can pose the question: Which possibilities for the origin of life are the most improbable? The statement of the impossibility of abiogenesis means that, according to empirical data at Vernadsky's time and his theoretical system, abiogenesis is the least probable way for the appearance of life. We do not know any period in the Earth's history, when no traces of living matter could be observed (Vernadsky, 1965, p. 202). Vernadsky found no need for abiogenesis. One finds neither indications of the beginning of life nor those of its ending (Vernadsky, 1965, p. 24).

Vernadsky tries to find support for his „negative" concept of the origin of life in the history of scientific worldview. Already in the foreword to the first edition of „The Biosphere" (1926), Vernadsky (1994, p. 316) emphasised that the idea that life had to have a „beginning" comes from „religious and philosophical searches". He proposed that the very idea of the end and the beginning has been adopted as a thought-stereotype of Christian theology. Vernadsky sees no necessity of applying these schemes to all natural phenomena, including life.

Vernadsky's space-time theory also plays an important role in his views on abiogenesis (see 2.1.). Thus, he saw some important reasons for rejecting abiogenesis and no convincing grounds for accepting it.

We know that there are some constant manifestations of reality in the Universe. Why should not we include „life" among them? Vernadsky (1991, p. 150) makes one of his most risky proposals:

> „Already now, the question of life in the Cosmos ought to be posed also in science. This is caused by numerous empirical data fundamental for biogeochemistry and seemingly indicating the fact that life belongs to such general manifestations of reality as matter, energy, space, and time. In this case, the biological sciences, along with the physical and chemical sciences, are to be included in the group of sciences studying the general phenomena of reality."

A 'positive' part of his concept of the origin of life is elaborated in more detail. The shortest way to introduce Vernadsky's concept is to say that *life appeared in the form of the biosphere*. In the article *„On the Conditions of the Appearance of Life on Earth"* (1931[1]), Vernadsky reduces the problem of the origin of life to the problem of the origin of the biosphere for the first time. He presents two basic arguments: (1) the space-time argument based on the principle of dissymmetry (Levit et all., 1999) and (2) the biogeochemical argument. The principle of dissymmetry was analysed by us in 2.1. Here I consider the second argument.

Vernadsky (1994, pp. 458-459) composes a table of the geochemical functions of life or biogeochemical functions. In the table, he shows how the different biogeochemical functions correspond to specific taxonomic groups. For example, the oxidising function is carried out by autotrophic bacteria and the function of destruction of organic compounds by chemoorganotrophic bacteria and fungi. By analysing this table, Vernadsky comes to three important conclusions:

1) All biogeochemical functions can be carried out by unicellular organisms;
2) One cannot imagine an organism (species) which is able to carry out all these functions;
3) In the course of geological time, different species may have replaced one another, but the biogeochemical functions did not change.

As we already know, Vernadsky later changed his mind in relation to the latter inference (3) and made the picture more complex by describing the evolution of the BGC functions. But this did not change the basic idea: life can exist only in the form of the biosphere, because the different BGC-functions have to be fulfilled simultaneously. Thus, Vernadsky (1994, p. 459) arrives at the conclusion that life can exist only when all biogeochemical functions are represented: „The first appearance of life occurring in the biosphere could not have been in the form of some separate organisms but in the form of the totality of organisms corresponding to the geochemical functions of life. Biocoenoses necessarily had to occur from the very beginning".

Thus, Vernadsky was on the side of the polyphyletic concept of the origin of life and appealed to specific biogeochemical arguments in order to substantiate his views.

However, we are faced with a new problem: if different species of unicellular organisms were necessary for carrying out different biogeochemical functions, then these different species had to exist from the very beginning of geological time. According to Vernadsky (1994, p. 459), evolution is a biospheric process and, hence, one should admit that this morphological diversity occurred somehow in a pre-evolutionary way. In contemporary science, a similar idea is defended by W. Krumbein (1996), who defines this „pre-evolutionary state“ as a *non-Darwinian evolutionary domain*.

Thus, we are back to the „negative“ side of the problem of the origin of life because the assumption that life should appear immediately in the form of the biogeocoenoses is also unacceptable. One can only assert that the morphological diversity of the first unicellular organisms could not develop via a „trivial“, biospherical, Darwinian evolution. Even nowadays, one cannot exactly describe a mechanism for the appearance of the pre-biospherical biodiversity.

2.3.8. *Dissymmetry of the biosphere*

Vernadsky created a theory of dissymmetry including the concept of spatial-temporal dissymmetry of living matter. In the following, *only* Vernadsky's concept of *spatial* dissymmetry of the biosphere will be discussed. The problem of temporal dissymmetry of the biosphere was discussed in 2.1.). This concept is a part of his theory of biological space and implies two meanings of the term dissymmetry: (1) a phenomenon called the *dissymmetry of life* (Krasnogorskaja, 1992, p. 25), of which the dissymmetry of protoplasm (Pasteur's dissymmetry) is a special case and (2) *dissymmetry of the biosphere.*

On purely mathematical grounds, Vernadsky considered those objects as dissymmetric which:

a) do not exactly coincide with their mirror images (geometrically, chemically, or energetically);
b) can exist exclusively or preferentially in spite of thermodynamic considerations in either of the two enantiomorphic modifications (left and right);
c) exist in one or two different modifications selectively and preferentially expressed in biogenic, bioinert or living matter.

The dissymmetry of Pasteur is a peculiar case of the molecular dissymmetry of life. Vernadsky talks of the dissymmetry of Pasteur when some chemical compounds typical for a living natural body statistically can and should exist in two modifications but exist only in one modification during the whole natural history of life (Vernadsky, 1965, p. 198). When the second modification is artificially synthesised, it differs from the natural modification in its properties. Evidently, the latter statement is trivial and does not allow us to talk about the dissymmetric character of space 'occupied' by living matter. In order to substantiate this idea, Vernadsky takes up the notion of the 'state of space' of P. Curie in addition to Pasteur's original articles. Vernadsky proposed a principle which he called the Curie principle: „Dissymmetrical effects (phenomena) can be brought about only by a dissymmetrical cause“. He realised that, if space is a kind of intelligible reality, then the causes and their effects must find themselves in the same state of space, i.e. the causes and their effects may not leave the boundaries of their common state of space (Vernadsky, 1965, p.182). It was remarked later, that the addition made by

Vernadsky is so important that the latter principle should be called the *Curie-Vernadsky principle* (Eliseev, 1989, p. 196).

Different states of space can be more or less separated, but also close to each other (Vernadsky, 1965, p. 169). Symmetry is a criteria of a state of space: „Symmetry characterises the different states of the Earth space" (Vernadsky, 1965, p. 169). The 'state of space' of any natural body can be determined by the *basic principle of symmetry*. This principle declares that the state of space of a natural body is determined by the minimum symmetry of its properties (Vernadsky, 1988, p. 379).

Thus the dissymmetry of Pasteur corresponds to a special case of symmetry-breaking because it is completely outside of the traditional laws of symmetry of the non-living natural world. Using the terms 'state of space', the 'basic principle of symmetry', and the characteristics of dissymmetry, we can perceive that the „state of space of a living natural body" will be characterised as dissymmetric, although some elements of its structure can be symmetric or asymmetric in a non-dissymmetric way.

The „space of life" or as a whole the „life field" is characterised by a dissymmetrical state of space, where the leftness and rightness and other factors are not symmetrical (identical) or statistically distributed (Vernadsky, 1997, pp. 217-218). In living matter, the properties of 'lefthandedness' and 'righthandedness' are not identical. The dissymmetric state of space of living matter is of a hereditary nature and reproduces itself during millions of years.

The problem of the dissymmetry of life implies not only the chemical dissymmetry of protoplasm (dissymmetry of Pasteur). It further implies the dissymmetry of isotopes and other atoms, which are selectively collected by living natural bodies. Age-dating of organic matter as well as the attribute „biogenic" of certain types of ore deposits and other natural phenomena are related to these novel types of dissymmetry introduced by Vernadsky. The preferential selection of certain isotopes and elements by biological systems is only possible under the terms of extracting negentropy from sun energy. Galimov (1989) states, that Vernadsky was the first to realise that dissymmetry applies also to these essential factors of living systems. He wrote: „Actually, the ferments organise the space in which the movement of biological matter takes place in a special way. Therefore it is possible to assume that the ideas and the notions of Vernadsky have been realised (albeit in slightly different terms and categories) in the contemporary theory of the biological fractionation of isotopes (Galimov, 1989). Vernadsky further includes the question of the relative abundance of some biologically important enantiomorphs in the discussion. He expanded the Pasteur-Curie principle of dissymmetry into new atomistic (isotopic) and geometric directions. Furthermore, the degree of morphological dissymmetry can be connected with the level of entropy.

Vernadsky realised that the chemical *dissymmetry of Pasteur* had to be distinguished from *morphological dissymmetry*. He further proposed a connection between these two kinds of dissymmetry. Experimental work in this line has been initiated by Gause (1940). He studied left- and right- spiralled colonies of *Bacillus mycoides* which were compared with the structures of enzymes.

Vernadsky's „morphological" and Pasteur's „chemical" (protoplasmic) dissymmetry embrace the phenomenon of the dissymmetry of life.

Vernadsky, however, mentioned two main kinds of dissymmetry which can be classified as: the *dissymmetry of life* and the *dissymmetry of the biosphere*. Vernadsky postulated that dissymmetry also can exist outside of the immediate field of life of a single organism. It will be, so to speak, a *dissymmetry of the second order* because it can be seen as a consequence of the activity of all living matter on Earth (the biosphere).

This „secondary" dissymmetry is observable in the structure of biogenic substances (e.g. organic fossils and organic matter as petroleum, coal and evaporative hydrocarbons). This includes the question of how long a biogenic product such as petroleum would keep its dissymmetry elements after being released from the body of a living being (specimen, population). Racemization of aminoacids e.g. is a time/space related physical/chemical phenomenon involving slow reactions of radicals. This racemization reaction, however, will only start and become significant when the compound in question has been released from a given living natural body (cell, organism, biosphere).

On the global scale, we find another phenomenon: Dissymmetry of the geospheres: „Not all geological envelopes and geospheres are ideally round", although there are no pure geological reasons for this fact (Vernadsky, 1965, p.110). Considering the form of our geoid (or better bioid, bioplanet (Kattmann, 1991)), we can expect all geospheres to be ideally round with the deviations caused by planetary (moon and planet or comet) attractors etc.(Vernadsky, 1965, p. 114). Already I. Kant was struck by the deviations of the planet Earth from the ideal spherical shape (Krumbein and Schellnhuber, 1990; 1992). Vernadsky analysed in detail the problem of dissymmetry of the biosphere and even made a table of the dissymmetry of the Earth's crust (Vernadsky, 1994, pp. 208-209). However, he did not come clearly (1965) to the idea of connecting both of these phenomena - the spatial dissymmetry of living matter and the dissymmetry of the geospheres, albeit he held life to be the most influential geological force.

Within the biosphere as a bioinert natural body, living matter is an active, ruling force. We could expect the biosphere to have some distinctive features of living matter and the inert part of the Earth to show the traces of the influence of fossilised living matter or bygone biospheres (e.g. cyanobacterial stromatolites and their products such as coal, oil and gas deposits).

If we do adopt the latter statement, we are faced with a new problem. According to observations, the area of dissymmetry spreads down to the envelope below the granitic layers of the crust. If the geological envelopes are dissymmetrical because they were and are influenced by the activity of living matter, how can the dissymmetry of, for instance, the region beyond the physical/chemical conditions of life, namely, of the granite and basalt layers with temperatures above the critical point of water be explained?

An answer to this question lies in the concept of bygone biospheres put forward by Vernadsky. The Earth's crust consists of several individual envelopes: the biosphere, the stratisphere (Vernadsky's term), the upper and lower metamorphic envelope, the granite and finally basalt/and/or eklogite envelopes. All of them were at a certain time in the past on the surface of the Earth, i.e. they are bygone biospheres (Vernadsky, 1965, p. 35; Lapo, 1987, p. 166). Vernadsky (1965, p. 75) explains this phenomenon by the vertical dynamics of the Earth's crust: „This [*the Earth's crust*] is a geologically mobile area of the planet, in which substance perpetually moves from the Earth's surface towards the centre of the Earth and, in the reverse direction, from the centre to the surface. All geological envelopes are 'genetically' connected with each other and, being taken as a whole, represent one single phenomenon".

The dissymmetry of the geological envelopes and the geospheres can be seen as caused by the presence of fossil and extant living matter on our planet. On the basis of the work of Vernadsky, the question of a kind of „living continuum" between the dissymmetry of life and the dissymmetry of the present and past biospheres can be posed. A precise mechanism for creating dissymmetry of the natural inert environment by living matter, however, must still be analysed. D. Anderson came to astonishingly similar conclusions: „There is the interesting possibility that plate tectonics" (i.e. the vertical and horizontal movement of parts of the crust and mantle which creates dissymmetry in a theoretically ideally spherical planetary body in the sense of Kant) „exist only on Earth because there is limestone generating life" (Anderson, 1984). The whole biosphere as a bioinert natural body can be approached from the viewpoint of the 'state of space'. E. Eliseev remarked in this connection: „Now one can say that different states of the Earth's space exist: these are the states of space of the Earth's core, mantle, lithosphere, atmosphere, stratosphere" (Eliseev, 1989, p.188). This could explain the astonishing physical, morphological and dynamic deviations of Earth from other planets of the Solar system by the creation of global biogenic dissymmetry.

2.3.9. *Cosmism of the Biosphere*

Vernadsky often writes that life is a planetary and a cosmic phenomenon. Sometimes he uses these terms synonymously: „Considering life phenomena as living matter shows that it is a planetary, i.e. cosmic phenomenon [Huygens principle]" (Vernadsky, 1965, p. 227). Sometimes the term *'planetary phenomenon'* is used to stress that some properties of the biosphere are defined by the properties of the Earth as a planet, for example, by the form and shape of the geoid.

Cosmism of life in this context means the following:

a) Life is not just a haphazard phenomenon in the Universe;
b) Life on the planet Earth is not the only possible form of life in the Universe;
c) The general laws of the Earth's biosphere are determined by fundamental cosmic regularities; as Vernadsky stressed, we should look for a manifestation of cosmic structure in the structure of the biosphere.

Vernadsky did not have a single empirical fact at his disposal to prove the principle of Huygens. That is why he often mixes wishful thinking with reality and declares, for example: „There are manifestations of life on Mars, without any doubt" (Vernadsky, 1965, p. 28).

The conviction of Vernadsky that life is a cosmic phenomenon is based on three main arguments. First, the properties of life are determined by the phenomena of a cosmic scale such as gravitation and solar radiation: „Studies of the morphology and ecology of green organisms long ago made it clear that the whole green organism (both in its movements and in its associations) is adapted, first of all, for its cosmic function: catching and transforming the sun's ray" (Vernadsky, 1994, p. 329). In the late works, Vernadsky generally talks about a dynamic equilibrium of material-energetic exchange between the biosphere and Cosmos (Vernadsky, 1965, p. 329).

The second argument seems obscure to the contemporary scientist. Vernadsky (1994, p. 321) writes that „a similarity of compounds of the exterior envelopes of celestial bodies like Earth, Sun and stars" show the essential (cosmic) character of life.

Third argument: the fact of the increasing significance of life in the processes of our planet shows by itself that life is a cosmic phenomenon.

The position of Vernadsky can be expressed in the following way: life is a cosmic phenomenon because the existence of life on Earth is secured by fundamental cosmic phenomena and because the uninterrupted increase of regular and lawful transforming activity of life can be observed. In other words, the fact that life is ideally fitted into the cosmic mechanism and plays a more and more significant role in it, shows the essential character of life (Vernadsky, 1965, p. 228):

> „It is logically inevitable to assume that we can find the same phenomena [life -*G.L.*] on other planets. The large scope of life and its significance on our planet does not allow the contemporary naturalist to think that life is an accidental (as Wolles [1822-1913] said 'providential') phenomenon, which is not connected with the planetary structure and is not represented in the Cosmos except for Earth".

If we take into attention that humans are also, according to Vernadsky, a regular part of the biosphere (see below: the noosphere concept of Vernadsky), this approach can be classified as a version of the *anthropic principle*.

And in this connection some further remarks should be added.

Barrow and Tipler provide three versions of the anthropic principle (AP). (1) The weak AP maintains that the observed physical and cosmological values are restricted by the requirement that carbon-based life exists. (2) The Strong Anthropic Principle (SAP) is a more speculative statement namely that „The Universe must have those properties which allow life to develop within it at some stage in its history" (Barrow & Tipler, 1986, p. 21). (3) The Final AP: „Intelligent information-processing must come into existence in the Universe, and, once it comes into existence, it will never die out" (Barrow & Tipler, 1986, p. 23).

In the works of Vernadsky, 'human living matter' is not only an 'observer' but an active substance in the Universe, which lawfully occurs, exists, and transforms its environment. Vernadsky would probably recognise that the observable Cosmos not only permits an observer but requires living matter as a lawful part of its organisation.

Compare:[13]

Barrow and Tipler (1986, p. 28): „The SAP of Carter has strong teleological overtones. It suggests that 'observer' must play a key role in (if not be the goal of) the evolution of the Universe".

Vernadsky (1994, p. 318-319): „Creatures on Earth are the fruit of a complicated cosmic process and are a necessary and lawful part of a harmonious cosmic mechanism, in which it is known that chance does not exist".

Thus, the views of Vernadsky are very close to what Barrow and Tipler call SAP. Furthermore, as we will see in 2.3.10., the position of Vernadsky on the question of the eternity of life and his noosphere concept allow to define his views on intelligent life as a preview of the Final Anthropic Principle. According to Vernadsky, life is a fundamentally eternal phenomenon. It creates its environment and this process can be spread to the whole universe (Aksenov, 1993, p. 87).

Compare:

FAP: „Intelligent information-processing must come into existence in the Universe, and, once it comes into existence, it will never die out".

Vernadsky: „This is caused by numerous empirical data fundamental to biogeochemistry and seemingly indicating the fact that life belongs to such general manifestations of reality as matter, energy, space, and time." (Vernadsky, 1997, p. 194). „Scientific thought as a manifestation of living matter *cannot be*, in its very essence, a

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[13] In comparing the individual statements one should bear in mind that Vernadsky wrote the works, which are quoted here, in the 1930's.

reversible phenomenon. It may be retarded in its development, but once having arisen and revealed itself in the biosphere's evolution, it bears in itself the possibility of unlimited development in the course of time" (Vernadsky, 1991, p. 25).

The idea of the cosmic nature of life is connected with all the important parts of Vernadsky's theoretical system. One of the arguments in favour of the idea of the eternity of life is his space-time theory (2.1.). Through the noosphere concept, this idea is tied up with the philosophy of science and the main principles of the biosphere theory.

2.3.10. *The Noosphere Concept*

The noosphere concept of Vernadsky is a system of ideas about the future of the planet Earth based on 'empirical generalisations' of the biosphere theory. That is why it is more correct to talk about the theory of the biosphere and its transition into the noosphere.

In spite of the extensive literature about the noosphere, there has been little attempts (Kutyrev, 1990; Ghilarov, 1994) to critically analyse this concept. In this chapter, I analyse the arguments of Vernadsky supporting his theory of transition of the biosphere into the noosphere.

In the noosphere concept, Vernadsky formulates one of his most closely-held intuitive convictions - his unlimited faith in the power of scientific thought. That is why the noosphere concept is seen, from the viewpoint of Vernadsky himself, as a culmination of his theoretical system.

He adopted the term 'noosphere' from E. Le Roy (Le Roy, 1927), who attended Vernadsky's lectures at the Collège de France (1922-1926). Le Roy stated that biological evolution is completed and with the appearance of man a new spiritual stage of evolution has begun. Le Roy called this new evolutionary stage the *noosphere*.

Vernadsky adopted only the term 'noosphere' but filled it with new content. He did not believe that the biological evolution is over. Vernadsky stated that the evolution of the biosphere goes in the direction of self-stabilisation by increasing the biogenic migration of matter. This evolution passes various stages (see above). Vernadsky calls the final stage of this process *the noosphere*. The most important characteristic of the noosphere is that the instrument of its stabilisation appears to be human reason, or better to say, scientific reason. Scientific thought is seen as a function of the biosphere or a planetary phenomenon (Vernadsky, 1991). Vernadsky's noosphere is inseparable from the biosphere and cannot be treated as a 'thinking layer'. Being a natural body, the noosphere includes living matter, the atmosphere, the lithosphere, the hydrosphere and the products of human technological activity. „The explosion of scientific creativity" in the 20th century (Vernadsky, 1991) is interpreted as a lawful phenomenon resulting from the whole course of evolution. On the wave of this explosion, humankind turns into the leading regulative factor in the biosphere. This responsible role makes it incumbent upon human society to undertake the necessary social reforms like the reconciliation and consolidation of humanity, elimination of war and hunger and a process of democratisation (Mikulinskij, 1989). One can say that the biosphere transforms itself into the noosphere by means of scientific thought. Science has a planetary or, better, cosmic assignment. It transforms our planet and lifts it up to a higher degree of biospheric *organisation*. The transition of the biosphere into the noosphere is a *lawful* process and will take place with an inevitability derived by the laws of nature (Vernadsky, 1991).

One can distinguish three basic statements of the noosphere concept which are subject to discussion:

1. Scientific thought is a function of the biosphere and thus a planetary (cosmic) phenomenon.
2. Scientific thought transforms the biosphere into the noosphere.
3. The coming of the noosphere is a lawful process.

Statement (1) can be, in its turn, divided into two subtheses:

1.1. The logic of science is „deeply and inseparable tied up with the biosphere“ (Vernadsky, 1980, p. 111).
1.2. Scientific thought is a lawful geological phenomenon.

Vernadsky called thesis (1.1.) „the basic empirical generalisation for the biosphere“. Yet this statement cannot be recognised as empirical generalisation. The statement is difficult to confirm or to refute, because „empirical“ is, first of all, observable or experimental. It is difficult to imagine how the connection between the logic of natural science and the biosphere can be proved by any immediate observation or experiment.

Subthesis (1.2.) could be proved if one could point out the related geological (biogeochemical) laws.

The statement (2) has also two aspects. The biosphere as reorganised by science can be seen both as reality and as utopia (Kutyrev, 1990). Thesis (2.1.), that man creates artificial ecosystems replacing the natural ecosystems in the course of time, is indeed a direct empirical generalisation.

Thesis (2.2.), that the process of replacing natural ecosystems with artificial ecosystems must lead „to the triumph of reason and humanism“ (Barsukov, Yanshin, 1988), seems to be a kind of utopia. Nevertheless, this claim can be substantiated if one finds a way to reduce (2.2.) to (1.2.) and to prove (1.2.).

Statement (3) can be proved if one specifies the laws determining the appearance of the noosphere.

So far it is clear that Vernadsky's noosphere is not a scientific concept in its entirety. However, we could save this idea, at least partially, if we could find in the persuasive arguments the texts of Vernadsky in favour of statements (1.2.) and (3). In short, in order to substantiate the noosphere concept, we must, first of all, prove that science is a lawful geological phenomenon inevitably turning the biosphere into the noosphere.

In Vernadsky's view, science is a lawful geological force. This claim is basic to the noosphere concept. If scientific thought occurs to be a matter of mere happenstance, the biosphere cannot be said to be lawfully turning itself into the noosphere by means of scientific thought.

In order to show the „natural“ character of the anthropogenic influence on the biosphere, Vernadsky examines technological activity as a 'black box'. He takes in account only the chemical compounds and the velocity of the biogenic migration of chemical elements.

According to the first and second BGCP's, the biogenic migration of atoms in the biosphere tends towards a maximum and the species (and forms of organisation) increasing the actual biogenic energy should appear. This means that the evolution of the biosphere has a *directedness*. Scientific reason increases the biogenic migration of atoms and thus lies in the natural course of the evolution of the biosphere. In Vernadsky's view, this is one of the arguments in favour of the lawful character of the appearance of scientific reason (and the noosphere).

The second BGCP is hardly acceptable as a universal scientific law. Indeed this principle reflects a tendency toward increasing biogenic migration of the elements. Yet it cannot explain the mechanism and the limits of the increase of biogenic migration. One could point out that the second BGCP can be formulated as a version of the principle of the struggle for existence: „In the course of the evolution, those species survive which by means of their lives increase the biogenic geochemical energy" (Vernadsky, 1993[1], p. 372). However, this version of the second BGCP contradicts Vernadsky's own classification of the kinds of the biogenic migration. As I already pointed out Vernadsky classifies these migrations into three kinds: (1) migration induced by the activity of microorganisms; (2) migration induced by the metabolism of *metazoa*; (3) migration induced by the mechanical activity of *metazoa* including humankind. Biogenic migration of the first kind is much more intensive than the migration of the second kind. However, if we accept the amendment of Kolchinsky (see above) and agree that the second BGCP is valid only within the framework of a kingdom, then it loose its power as an argument in favour of the noosphere.

After all, the first and second BGCP's do not determine the optimal rate of biogenic migration. They say nothing about the geophysiological functionality of the increasing biogenic migration induced by the thoughtful activity of man. What follows from the analysis of the relations between human activity and BGCP's is the inference that this activity does not contradict the tendency indicated by these principles.

The first and second BGCP's, being accepted, are followed by the inference that the biosphere tends towards a maximum of active (kinetic) energy and that the forms of organisation and species, or species associations which satisfy this requirement, should occur in the biosphere. However, the principles do not specify which forms will occur.

The latter must be clarified by the third principle (concerning the directedness of the evolution of the biosphere) or the *empirical generalisation of J. Dana* (1813-1895). This generalisation connects the evolution of the biosphere to the development of a central nervous system in some species (*cephalization*) (Vernadsky, 1991, pp. 21, 22). Human reason and a higher level of biospheric organisation are the results of cephalization.

However, the Dana principle is a pure empirical generalisation and has little explanatory power. The origin of the human brain as a material base of scientific reason does not contradict this empirical generalisation. Yet this generalisation does not make it possible to talk about the lawful origin of intelligence in the biosphere. Quite the reverse: Many of the leading contemporary evolutionists (T. Dobzhansky, G. Simpson, F. Ayala, E. Mayr), taking in account the likelihood of evolution to human-level intelligence, hold, that „there is no indication in the geological record that the evolution of intelligence is at all inevitable" (Barrow & Tipler, 1986, p.133).

Vernadsky also tried to find evidence for his noosphere concept outside of the pure biogeochemical cycle of thinking in his own space-time theory. Here I point out some connections between the noosphere concept and the space-time theory of Vernadsky.

The essential key to the space-time theory of Vernadsky is dissymmetry (Levit et al., 1999). The space-time of living matter is dissymmetric and the time of living matter appears to be irreversible. This enables us to say that the space-time of the biosphere is dissymmetric. This, in turn, means that the time of the biosphere and, accordingly, the essential processes of the biosphere are irreversible. Vernadsky wrote:

> „The irreversibility of the evolutionary process is the result of a characteristic which distinguishes the living matter in the geological history of the planet from the inert natural bodies and processes of the planet. One can see that irreversibility is tied up with the

> special qualities of the space occupied by the bodies with a special geometrical structure, a special *state of space* (as P. Curie said)" (Vernadsky, 1991, p. 24).

If so, then the phenomena described by the BGCP's and the Dana principle appear to be irreversible as well as the whole evolutionary process (Vernadsky, 1991, p. 24). This should be an answer to the question about a theoretically possible reverse of the evolutionary process described by the BGCP's and the principle of Dana.

This hypothesis of Vernadsky gives rise to some doubts. The irreversibility of time and the irreversibility of the evolutionary process are two different things. The only condition which must be fulfilled to assure that we are dealing with absolutely irreversible temporal phenomena (in the sense of Vernadsky), is the prohibition of absolutely symmetrical temporal events. For example, a solid crystal in the solution can be produced, then dissolved again and then reproduced as a crystal with the same crystalline structure. This process and the time in which this process takes place will be reversible, according to Vernadsky. Examining living matter, we observe the opposite picture. If we take into consideration, for example, a natural mutation, it would be clear, that a return of the mutant to the very organism from which it had separated is impossible (even in case of reversible mutations). Vernadsky (1991, p. 17) stated that „any single *individual* of living matter differs *chemically* from the others". The methodological position of Vernadsky can be characterised as a version of the *principle of Leibniz* as it represented by A. Gruenbaum (1974).

However, temporal irreversibility of the life process does not guarantee the irreversibility of progressive morphological evolution. Irreversibility of time is insensitive to the directedness of the evolutionary process because both evolution and degradation would be equally irreversible from the viewpoint of temporal symmetry. That is why the space-time theory of Vernadsky, as it is, cannot be used as an evidence for the irreversibility of the biosphere evolution and the inevitability of formation of the noosphere.

In Vernadsky's view, once scientific thought appeared, it inevitably led to the noosphere. Partly, it is connected with the peculiar spatial-temporal properties of living matter: „Scientific thought as a manifestation of living matter *cannot be*, in its very essence, a reversible phenomenon" (Vernadsky, 1991, p. 25). This viewpoint was already criticised above.

According to Vernadsky, the *irreversibility of the transition into the noosphere* appears to be a concept of social evolution based on the biosphere theory. The statements of Vernadsky concerning the irreversibility of the transition into the noosphere are the most debatable in his theory. One of the most illustrative examples shall be quoted:

> „A civilisation of 'cultural humanity' (being a form of the organisation of a new geological force created in the biosphere) *cannot disappear or cease to exist*, for it is a great natural phenomenon corresponding historically, or more correctly, geologically, to the established organisation of the biosphere. Forming the noosphere, the civilisation becomes connected through all its roots to its terrestrial envelope (*biosphere*), which has never happened in the previous history of the mankind to a comparable degree" (Vernadsky, 1991, p. 40).

This quotation clearly shows that Vernadsky commits the methodological error of extending the methodology of natural science to the domain of social evolution. He puts human reason on the same level as the other biospherical phenomena. Humans appear to be deprived of their freedom of choice. This way of thinking can be classified as a version of social determinism:

> „All the fears and reasonings of the philistines, representatives of the humanities, and philosophy about the possibility of the fall of civilisation are tied up with an underestimation of the power and depth of geological processes like the one we are now experiencing, namely, the transition of the biosphere into the noosphere" (Vernadsky, 1991, p. 45).

This quoted passage can be interpreted as follows: Geological processes are natural processes. Man, being a natural phenomenon, greatly influences the geological processes. Hence, this very influence also can be treated as a kind of natural process. Nature cannot contradict itself. So civilisation (the transition of the biosphere into the noosphere) cannot be interrupted.

All processes which take place in nature without participation of man are called *natural* independently from their „depth and power". Thus the biosphere was a natural self-regulating system before the appearance of humanity. With the appearance of human beings endowed by consciousness and free will, one can talk about artificial things and processes. Man creates, for example, simplified artificial biogeocoenoses, which cannot survive without his help (Kamshilov, 1979).

Such biogeocoenoses cannot be classified as natural. Man could make all the natural biogeocoenoses into artificial biogeocoenoses and destroy the natural equilibrium of the biosphere. And the „depth and power" of the human influence on these biogeocoenoses would not allow us to classify this catastrophe as a natural event.

It can be stated that not a single discovery of contemporary geology (palaeontology, paleoecology) contradicts a possible downfall of the „civilisation of cultural mankind".

In order to understand how Vernadsky, a naturalist, could afford such an extravagant prophecy, we must recall that human reason is for him, first of all, scientific reason. Science, in its turn, is seen by Vernadsky as a natural phenomenon, which cannot be anti-natural and is, according to this, amoral by definition. It looks as if scientific reason escaped the First Sin, while the other parts of the human mind are evidently „post-paradisic".

The evolution of life on Earth is a lawful process which leads to the appearance of human reason and scientific thought. Hence, scientific thought is a regular natural terrestrial phenomenon. Now, it seems logical to say that *scientific thought is a planetary phenomenon which cannot destroy the planet which begot it.*

This way of thinking ignores the fact that human thought is a phenomenon of a peculiar nature and cannot be equated to the other manifestations of the biosphere. Even if we accept that it is a regular, lawful manifestation of biospheric evolution, it would not substantiate a thesis that it cannot perform a destructive role in the biosphere. Theoretically, we can construct a model (mathematical, computer-model) of a system, which will be destroyed by a regular (lawful) element of that system. Moreover, even if scientific thought is of a „supermoral" nature, Man as an owner of this thought is a very unstable and dangerous element in the system '*man - nature*'.

Thus, neither the planetary character of scientific thought (the lawfulness of its appearance and formation) nor the power and intensity of human influence on geological processes can be used as arguments in favour of the irreversibility of formation of the noosphere.

We can consider one more problem which occurs in this connection: if human thought is a planetary natural phenomena, it should be natural in all its manifestations. One can ask how natural, supermoral, objective scientific thought can co-exist in the human mind with subjective and often destructive philosophical, and religious thought? How can man prove scientific thought is the most 'natural' of human 'thoughts'?

In order to complete his noosphere theory, Vernadsky had to substantiate the ambitions of science to represent a directive force of the noospheric evolution. In the other words he had to create his own „noospheric" philosophy of science. I analyse his philosophy of science in the chapter 2.2.

The system of principles and generalisations created by Vernadsky to describe the biosphere can be classified as a scientific theory. However, in our view, the concept of the transition of the biosphere into the noosphere does not appear to be a scientific concept, although Vernadsky claimed this concept to be scientific and empirical. The arguments of Vernadsky which we find in all parts of his theoretical system are rather speculative. The Dana principle is indeed an empirical generalisation, but it cannot be used as an argument in favour of inevitability of the origin of scientific thought. The second BGCP, even being accepted as an empirical generalisation, does not give support to the noosphere. The arguments following Vernadsky's space-time theory are also, as we have seen, methodologically inconsistent.

To sum up: the empirical basis of the biosphere theory does not support Vernadsky's claims about the inevitable and lawful transition of the biosphere into the noosphere. This does not justify to treating the idea of the noosphere as a scientific concept.

3. THE THEORETICAL SYSTEM OF VERNADSKY IN THE CONTEXT OF CONTEMPORARY SCIENTIFIC THOUGHT

3.1. *THE BIOSPHERE AND THE NOOSPHERE THEORIES OF V. I. VERNADSKY AND P. TEILHARD DE CHARDIN*

3.1.1. *Introduction*

Comparative investigations on the theories and terminology of Vladimir Vernadsky and Pierre Teilhard de Chardin have been already discussed in the scientific literature (Serafin, 1987; Grinevald, 1996; Fuchs-Kittowski & Krueger, 1997, Löther, 1998).

Although the ages of Teilhard de Chardin (1881-1955) and Vernadsky (1863-1945) differed, they were at the comparable level of scientific maturity concerning the growth of their biosphere-noosphere theories. As we know Vernadsky first presented his views on the biosphere systematically when he published *The Biosphere* in 1926, although he began using the term *biosphere* much earlier (1911). In his *Essays on Geochemistry*, lectures written in Petrograd (St.-Petersburg) in 1921, Vernadsky used both of the most important terms of his theory: living matter and the biosphere, although he made the first clear definition of the biosphere in 1923. At the same time (1921), Teilhard used the term *biosphere* in his „*The Face of the Earth*" for the first time (Grinevald, 1996, p. 41). From 1938-40 Teilhard wrote one of his basic works *Le phénomène humain* (1955) (The Phenomenon of Man) where he presented the biosphere and the noosphere concepts. At the same time (1936-38), Vernadsky wrote his „*Scientific Thought as a Planetary Phenomenon*" where he used the same terminology. Both scientists adopted the term 'biosphere' from the works of the Austrian geologist Eduard Suess (1831-1914), who had coined this term in 1875. Developing the theoretical insights of Suess, both scientists left the boundaries of descriptive natural science and tried to create all-embracing theoretical systems including elements of philosophy, social sciences and authorised interpretations of the evolutionary theory. The most general objective of the two theoreticians were also similar: to prove the „non-accidental" character of the Earth's biota by creating a global theory of life. Both thinkers aimed to combine separated segments of their contemporary science by creating an integral picture.

It is remarkable that both scientists derived global theoretical generalisations from descriptive natural disciplines, and in general, were at a comparable level of scientific knowledge. Teilhard was a professor of geology at the Institut Catholique in Paris, and was known as a Jesuit Father, palaeontologist, and paleoanthropologist. Vernadsky was a professor of mineralogy at the Moscow University, a geologist and crystallographer by profession, and the founder of biogeochemistry. Furthermore, the two scientists were personally acquainted and are said to be influenced by one another. K. Bailes (1990, p. 162) reports that Vernadsky's lectures at the Sorbonne in the 1920s were attended by Teilhard de Chardin and his close friend Edouard Le Roy (1870-1954). The latter was influenced by biogeochemical ideas of Vernadsky and mentioned Vernadsky many times (Le Roy, 1927, pp. 142-143, 159, 163). Teilhard (e.g., 1959, p. 203) also quoted Vernadsky in connection with his biosphere concept. Vernadsky (1965, p. 328) himself wrote that Teilhard de Chardin and Edouard Le Roy elaborated the theory of the noosphere based on his biogeochemical concept of the biosphere. Vernadsky, in turn, borrowed the term 'noosphere' from lectures, writings, and from conversations with Le Roy. Grinevald (1996, p. 41) writes: „Together, the two unorthodox Catholic thinkers (Teilhard de Chardin and Le Roy - *auth.*) discussed the new scientific idea of the biosphere and, in collaboration with the Russian scientist, Vladimir Vernadsky, then in Paris, developed the notion of the noosphere".

Both theoreticians helped to give birth to the biosphere and noosphere concepts, however Vernadsky's and Teilhard's concepts of the biosphere and the noosphere differ in crucial points. They based their theories on a comparable body of empirical data, and pursued similar general objectives. However, they created two different theoretical worlds.

In this chapter I analyse the methodological similarities, and disparities between the two theories, and point out that their divergence can be connected with the differing scientific and ideological experience of the two thinkers.

Comparative tables of the two theories are given as an appendix to the chapter to clarify the general comparative picture of the two theories' final claims, and to avoid an excessively detailed comparison that would overload the text.

3.1.2. *The Biosphere, Living and Inert Matter, and the Evolution towards Intelligent Life*

The general methodological principle proclaimed by Vernadsky and Teilhard de Chardin can be expressed as purely phenomenalistic, being absolutely, and completely scientific. For example, Teilhard (1961, p. 300) writes about the "perfect scientific legitimacy" of the views he has put forward.

Both thinkers sought to fit the presence of intelligent life on Earth into a scientific worldview. The objective of Vernadsky and Teilhard de Chardin was to argue that evolution toward intelligent life was a lawful process of cosmic significance. They also saw evolution as a directed process.

a) „Life ...is a controlled (*dirigé*) process" (Teilhard, 1961, p. 151).
b) „We take the evolutionary process over geological time as a directed process" (Vernadsky, 1965, p. 193).

For Teilhard, in contrast to Vernadsky, prebiotic evolution was a directed process. The *directedness* of the evolution of life meant, in both cases, a movement from the primitive (rudimentary) forms of life and intelligence to their more advanced forms. Teilhard. The idea of the *directedness of evolution* implies in both cases that the growth of intelligence is a lawful process. As Vernadsky puts it: „He [man - *auth.*] is an inevitable manifestation of a great natural process having lasted in a regular way for at least two billion of years" (1997, p. 31)

Both Vernadsky and Teilhard de Chardin paid a lot of attention to the already mentioned *Dana principle.* J. D. Dana (1813-1895) had noted that in the course of geological time, a certain part of the planet's inhabitants acquired an increasingly complex central nervous system (*cephalization*). Vernadsky connected this generalisation with the irreversible growth of living beings' intellectual capacities in the course of geological time. The irreversibility of the *cephalization* process was important also for Teilhard de Chardin.

However, both scientists transformed this „empirical generalisation" of increasing cephalization into theoretical argumentation differently. Teilhard, a palaeontologist, endeavoured to explain the appearance of the reflective mind through the evolution of organisms, and to predict its future development by transforming the whole history of the universe into a „biological history". Vernadsky, a biogeochemist, aimed to place humankind into a geological history by investigating the relationships of inert and living matter.

Teilhard de Chardin applied a 'mathematical-like' approach by extrapolating a straight line in a coordinate system from a field of positive values to a field of negative values. He began at the atomic level and tried to represent the state of affairs as if the Dana principle in the living world were a special case of the more general principle of the evolution of matter.

Evolution begins with elementary particles which appear „suddenly" and, from the very beginning, manifest the „granular" property of matter (Teilhard, 1961, p. 49). „Granulated" and still unified matter evolves towards more complex forms and, thus, underlies from the beginning „the great biological law". The universe is a „closed quantum" and nothing can appear which did not already exist. When a material body moves with a velocity comparable to the velocity of light a correlation between mass and velocity becomes significant. In everyday life this correlation is insignificant, but this does not mean that our everyday life breaks the laws of relativity. By analogy, an evident presence of consciousness or „interior world" in the human being shows that this property, in the terminology of Teilhard „the within of things", must be inherent to matter in general. Under the cover of inert matter, a „biological layer" exists and existed from the very beginning. This means that the beginning of „biology" and the beginning of the initial granulated World were simultaneous events.

Teilhard saw biological evolution as continuation of pre-biological evolution, and the growth of mind as regular process, in which there is a gradual concentration of the „within of things". Intelligent life is a result of the lawful evolution of unified matter, which from the beginning was dichotomous, having an interior and exterior side. It is therefor extremely important for Teilhard to show the similarity of living and inert substances. He proclaims the absence of an impassable border between the two kinds of matter. Hence, there must be transitional forms between life and non-life in the theoretical system of Teilhard de Chardin. For him, a virus is an example of such a transitional form.

To Vernadsky, it was clear, that the evident growth of the central nervous system during evolution (the Dana principle) should serve as evidence for a conclusion concerning the lawful character of intelligent life's origin on Earth. It was clear to Vernadsky that one can trace the development of the nervous system from the most primitive examples to its present forms, and that this development is connected somehow to the growth of mind. At the same time, from his practical work as a biogeochemist, Vernadsky knew that the intelligent part of the biospheric substance ('*human substance*' is an expression of Vernadsky) was inseparably connected with the rest of living matter (totality of living organisms) and with the biosphere as a self-regulating system including the inert environment. He knew that living and inert substances manifest sharply different properties, and are therefor in principle different kinds of matter. However, he saw the process of evolution as a wholly biospheric phenomenon, so that all events can be seen as having their specific function in this larger process. Vernadsky knew from his scientific experience, that the evolution of the biosphere is caused by living matter, and called inert matter „inert" or „sluggish" primarily because of its passive character.

The growth of mind on Earth can be connected with the general properties of living matter. This statement may be extended, in that, if living matter is of a unique nature, then the human mind is a lawful phenomenon; if living matter is just a modification of an inert substance, then life and man are accidental events. Thus, in contrast to Teilhard, it was important for Vernadsky to show the contrast between living and inert substances.

Vernadsky, as well as Teilhard de Chardin, aimed to prove that life is a regular, non-sporadic, non-transitory phenomenon in our universe. The important generalisations and theoretical statements in both theoretical systems serve to prove this main assertion. However at this juncture, Teilhard and Vernadsky proceed by different pathways: Teilhard assumes, that life is an eternal, constant phenomenon, because each single atom contains a rudimentary form of life inherent to all matter. In the Universe of Teilhard, the atom has interior and exterior properties. Teilhard (1961, p. 57) associates the interior properties of the atom („within of things") with life ('biological layer'), the exterior properties („without of things") with the world of physics and chemistry. An atom can therefor be adopted by a living organism and become part of living matter. Vernadsky proposes, on the contrary, that life is non-transitory, *because it is strictly separated* from the inert environment. From this statement follows the inference that life is an eternal phenomenon. That is why Vernadsky, unlike Teilhard, pays so much attention to the problem of the distinctions between inert and living matter. According to Vernadsky, living matter manifests spatial-temporal-energetic peculiarities which separate it sharply from the inert environment (see 2.1.), and living matter is connected with the inert environment only through a biologically controlled flow of atoms. The biologically controlled atomic exchange between living and inert substances is possible, because an atom of this universe bears no peculiar living or non-living properties. It would be incorrect to assume that life and non-life are already present on the atomic level, because an atom achieves its significance via its involvement in a two-level system: *inert environment - living organism*. Which kind of space-time-energy continuum our atom finds itself in is quintessential in the theoretical world of Vernadsky. The biogenic exchange of atoms between the two states is necessary because of the opposition of the two substances.

The biosphere, according to Vernadsky, is a *geological stratum* and, at the same time, a *self-regulating system* including both living and inert constituents (see 3.1.). He formulated this opinion based on the theoretical supposition of dichotomous matter and from his experience as a biogeochemist. In contrast, the biosphere of Teilhard de Chardin is strictly constituted from the aggregate of living organisms. As a palaeontologist, he concentrated on the self-organisation of living matter and, as a theologian, he thought about the future „splitting" of biosphere and noosphere. Therefor, the biosphere of Teilhard is a step in the process of this evolutionary break.

The most significant differences in the theories of the biosphere of Teilhard de Chardin and Vernadsky originate from their interpretations of the nature of life. Teilhard assumed abiogenesis occurred because it was in accordance with his concept of dichotomous matter. Vernadsky did not assume abiogenesis occurred because from his viewpoint it would be incompatible with the affirmation of the crucial substantial-energetic difference between living and inert natural bodies. Teilhard concentrated his efforts on investigating the similarities between the two kinds of matter because it was important for him to demonstrate the material and spiritual unity of the world. Vernadsky, on the contrary, sought to describe the fundamental border between living and inert substances from the biogeochemical viewpoint, because this played an important role in his understanding of life as a regular, non-sporadic, perpetual phenomenon in the universe. Accordingly, Teilhard did not see that geogenesis is an effect of the presence of life on Earth. In his theory, *geogenesis* transforms itself into *biogenesis*, whereas Vernadsky stressed that living matter is an acting part of the biosphere producing free geochemical energy. Geogenesis, according to Vernadsky is a natural consequence of the presence of life on Earth. Thus, the difference between Vernadsky's and Teilhard's views on the nature of life led them to different interpretations of the biosphere. A complete list of the differences is summarised in table N2.

3.1.3. *The Noosphere*

Both Vernadsky and Teilhard de Chardin claimed that evolution is a directed process, and their schemes coincide approximately until the appearance of intelligent life. From there Vernadsky's and Teilhard's evolutions diverge because they imply entirely different goals. Vernadsky and Teilhard sketched two absolutely different pictures of the noosphere, although both of them claimed to be strictly „phenomenalistic" and to base their theories on pure „empirical generalisations".

Vernadsky understood the noosphere as a lawful stage in the evolution of the biosphere. The crucial characteristic of his last stage of biospheric evolution is the dominance of scientific reason. Science influences, accelerates, transforms and takes under its control the „natural" biospherical processes. At the same time, science is also a natural planetary phenomenon. From Vernadsky's viewpoint the noosphere is not a new „sphere" on the Earth's surface, because all noospherical events take place in the frame of the biospheric geological stratum. There is no mysticism in this view, and Vernadsky never discussed the temporal limits, or the possible end of the noosphere.

Teilhard's viewpoint allows him to depict an imaginary evolution of the noosphere. The psychic, interior side of matter or so-called „radial energy" directs matter to higher levels of organisation which culminate in the end of the evolutionary process. This end is external to the evolution itself. The Earth's noosphere will be replaced by a super-mind and will coalesce into a so-called *Omega-Point*. As Teilhard put it (1961, pp. 273, 287-288):

> „This will be the end and the fulfilment of the spirit of the earth.
> The end of the world: the wholesale internal introversion upon itself of the noosphere, which has simultaneously reached the uttermost limit of its complexity and centrality.
> The end of the world: the overflow of equilibrium, detaching the mind, fulfilled at last, from its material matrix, so that it will henceforth rest with all its weight on God-Omega".
> „...the end of all life on our globe, the death of the planet, the ultimate phase of the phenomenon of man".

Teilhard saw the noosphere as a transitional stage of evolution from the biosphere to the Omega-Point. He describes the noosphere as a *layer* over the biosphere, because to him it is the beginning of a separation process. The radial energy enters a stage of visible dominance and partial separation on the way to total independence.

The Omega-Point concept in the theory of Teilhard follows logically from the dichotomous characters of matter and energy which appear at the atomic level. The *interior side* of matter, of atoms, implies the constant presence of Omega from the very beginning of the universe. „A present and real noosphere goes with a real and present centre" (Teilhard, 1961, p. 269). This is the principle of the insistent movement toward the super-mind in the course of evolution and beyond the evolutionary mechanisms. The transcendental Omega „slips out" of the material, spatial-temporal world, finally resulting in a pure state of being without any material constituents. Therefor, an endless life within the material world would be a theoretical impossibility for Teilhard.

In Vernadsky's theoretical world, the idea of Omega would be unthinkable, because it is incompatible with basic biogeochemical concepts. According to the first and second biogeochemical principles, the biosphere evolves in the direction of increasing stability and acceleration of the biogenic migration of atoms. To Vernadsky, human thought appears in the noosphere as a lawful manifestation of biospheric evolution, which can only be separated from it in abstraction. He expresses in his noosphere concept that the reflective mind will expand to control the whole geological stratum, and did not exclude a further spreading of humans throughout the Cosmos. Therefor, Vernadsky's noosphere has no theoretical end.

The noosphere conception of Teilhard de Chardin and the noosphere conception of Vernadsky have nothing in common, outside of the term „the noosphere" used by both theoreticians.

3.1.4. *Methodological Remarks*

The above comparison of the biosphere-noosphere theories of Vernadsky and Teilhard de Chardin attempted to remain in the framework of the inner logic of these theories. Herein methodological remarks will be made from a detached perspective.

If one compares the phenomenological basis of the theories of Vernadsky and Teilhard de Chardin with their deductions and predictions, one is faced with some methodological inconsistencies. In both cases the theoreticians take the same basic methodological liberty. Without claiming an exhaustive definition of this problem, it can be formulated as follows: a certain phenomenon (process) which exists on Earth is analogically extrapolated either in time or in space (or, even, in a spaceless-timeless domain) without any convincing grounds. For example, Teilhard's biosphere-noosphere theory implies that, if one can evidently observe intelligent life at present, one can extend the phenomenon of intelligent life which is observable today to the pre-biotic past, the post-biospheric future and the timeless domain of the Omega-Point. Such assumptions are not theoretically forbidden, but may be in contradiction to the basic phenomenology principle of Teilhard, in that his inferences extend far beyond any empirical data. Trying to substantiate the lawful, non-contingent character of the origin of intelligence, Teilhard de Chardin claimed: „It is impossible to deny that, deep within ourselves, an 'interior' appears at the heart of beings, as it were seen through a rent. This is enough to ensure that, in one degree or another, this 'interior' should obtrude itself as existing everywhere in nature from all time."[14] In contrast, one could claim that this „interior" (intelligence, soul, spirit) is intrinsic only to living beings and appeared due to the play of chance. There are no scientific grounds for claiming that the origin of intelligent life is tied up with the complexity of the organisation of matter without taking into account what kind of complex structures bear intelligent life. There is also no reason for claiming that the level of the human spiritual abilities will be powerfully heightened in the future. The idea that one day the spiritual side of matter will separate itself from its „material" basis seems to be not only non-phenomenological, but even non-logical, if one accepts that the disclosure of the „spiritual side" of matter is accounted for by matter becoming more complex.

Similar methodological inconsistencies can also be found in Vernadsky's theoretical construction, which also claimed to be derived from „empirical generalisations". He assumed that one observes the steady acceleration and complication of atoms' biogenic

[14] Ibid., p. 56.

migration in the course of evolution (first and second biogenic principles). One also observes the increasing complexity of a nervous system and connected with it, the growth of intelligence, which, in its turn, continues the natural course of biogenic migration. Hence, one can predict these processes will be continued in the future (for more details see 2.3.):

> „The noosphere, that is, the biosphere reworked by scientific thought, produced by a process that took place during millions, perhaps billions of years, and created the *Homo sapiens faber*, is *not a short-time and transient geological phenomenon*. Processes which took many billions of years, cannot be transient, cannot cease. It follows that the biosphere will transform (one way or another, sooner or later) into the noosphere, that is, in the history of the peoples populating it, those events will happen which are necessary for this transformation, and do not contradict it" (Vernadsky, 1991, p. 40).

The problem of substantiating this „empirical generalisation" is that one may ask why „the processes which took many billions of years cannot cease"? There is no empirical grounds for accepting or rejecting this proposal, nor is there any grounds for trusting Teilhard de Chardin's claims (based on the same scientific data) that planetary evolution „will cease", because the planet will die (Teilhard, 1961, p. 273).

Thus, both Vernadsky and Teilhard de Chardin take the same methodological liberty. By declaring the principle of phenomenology, they make prophecies which go far beyond any empirical generalisation.

A second interesting methodological paradox involves the problem of reduction. Both thinkers, Vernadsky and Teilhard de Chardin, tried to appeal to the physical-chemical level of argumentation in order to present their ideas as strictly scientific claims. Thus in the epilogue to „*The Phenomenon of Man*" Teilhard (1961, p. 300) declares:

> „Reduced to its ultimate essence, the substance of these long pages can be summed up in this simple affirmation: that if the universe, regarded sidereally, is in process of spatial expansion (...), in the same way and still more clearly it presents itself to us, physico-chemically [*underlined by me - auth.*], as in process of organic *involution* upon itself (...) - and moreover this particular involution 'of complexity' is experimentally bound up with a correlative increase in polarisation, that is to say in the psyche or consciousness".

Both Vernadsky and Teilhard de Chardin tried to bring physical-chemical arguments into a discussion about the peculiarity of living matter in an inert world. In the case of Teilhard de Chardin, it is contradictory to prove the fundamental difference of the „interior of things" and the „exterior of things" by appealing to the physical-chemical level, because it is logically paradoxical.

Vernadsky also makes this mistake when trying to appeal to geochemical laws by discussing the inevitable coming of the noosphere. It is impossible, in principle, to predict future social and spiritual events by appealing to geochemical regularities of the past.

Vernadsky and Teilhard de Chardin constructed different concepts of the noosphere and biosphere according to their purposes by interpreting the empirical facts in favour of their theoretical demands. This is clearly shown by their interpretation of molecular dissymmetry. In 1848, L. Pasteur discovered a phenomenon that he later defined as „molecular dissymmetry". He discovered that some of the basic organic compounds found in living matter (crystals) are structurally different from those usually found in the inert environment. Although there are two possible isomers of these organismal compounds which could theoretically exist, one finds pure steric compounds in the protoplasm of the living organisms. Pasteur stated that both the crystallisation processes and the biochemical processes of living matter result in a definite leftness and rightness of produced compounds. He called this phenomenon *dissymétrie* and defined it as a demarcation line between living and non-living nature (Pasteur, 1922, p. 343).

The term of Pasteur was translated into German and English as asymmetry and then came back as 'asymmetry' in the works of Teilhard de Chardin (e.g., 1955, p. 98). Vernadsky used the term in its original form (dissymmetry). Therefor, we will refer to this phenomenon as *dissymmetry* in both cases to escape further confusion. Without doubt, Teilhard and Vernadsky were using two words to describe the same phenomenon. Teilhard (1961, p. 74) wrote:

> „The biologists have noted that, according to the chemical group to which they belong, the molecules incorporated into living matter are all asymmetrical in the same way, that is to say if a pencil of polarised light is passed through them they all turn the plane of the beam *in the same direction* - either they are all right-rotating or left-rotating according to the group taken".

In Teilhard's view, dissymmetry shows that the living matter of the biosphere is homogenous substance because all molecules of living substance are equally dissymmetric. This shows that the living matter of the biosphere is only one of the theoretically possible living substances and that the biosphere is only one of the theoretically possible biospheres. From this, all living matter of the biosphere must have appeared at approximately the same time. It also follows that the whole of living matter came into existence from the same origin. Therefor in the light of dissymmetry, the contemporary hypothesis of independent life pulsations (that life on Earth appears and disappears in the course of geological time) is evidently wrong. This indirectly proves that in pre-biospheric time, evolution manifested the same technique of „directed chance" (*Hasard dirigé*) as in the biospheric period. Dissymmetry shows, that the occurrence of life on Earth was a unique event. This occurrence parallels the singularity of the first appearance of the atomic nucleus and electron. The peculiarity of this event and the mortal nature of organisms explains the necessity for the self perpetuation of life. It is therefor clear that *abiogenesis* must not only have taken place once on Earth, but that this occurrence changed the environment in such a manner as to disallow further abiogenic events.

In Vernadsky's view, the spatial dissymmetry and temporal irreversibility clearly demonstrated in organisms, indicates that living matter occupies a peculiar dissymmetric space-time continuum. This dissymmetrical space-time is strictly separated from the symmetrical space-time of inert natural bodies. This separation of space-time explains the necessity for the self replication of living matter. Living matter of the biosphere is a homogenous substance in that all molecules of a living substance are equally dissymmetric; and existed from the very beginning in the form of the biosphere. The impossibility of abiogenesis is accounted for by dissymmetry, because dissymmetrical effects (phenomena) can be brought about only by a dissymmetrical cause (Vernadsky, 1991, pp. 25, 167, 170-171). This concept plays an important role in substantiating the noosphere theory.

The same phenomenon of molecular dissymmetry is interpreted differently in both theories and is applied for different purposes. Teilhard used dissymmetry in order to prove abiogenesis, while in Vernadsky's theory, dissymmetry is used to prove the impossibility of abiogenesis. This illustrates the assertion that, although they both claim to be purely phenomenalistic drawing solely from empirical generalisations, the same phenomena are interpreted differently according to the inner demands of Teilhard de Chardin's and Vernadsky's theoretical systems.

3.1.5. *Conclusions*

Both thinkers used the scientific data of their time as the empirical basis for their theories. In both theories, the same basic terminology is used: the biosphere, the noosphere, cephalization, living matter, etc. Both theories contain similar methodological principles, such as, the declared principle of phenomenology and the implicit principle of teleology. Nevertheless, Vernadsky and Teilhard created theories with differing views on crucial subjects. Vernadsky rejects abiogenesis; Teilhard accepts abiogenesis; Vernadsky claims that terrestrial intelligence is unthinkable outside of the biosphere; Teilhard brings up the idea of the „splitting of evolution". The concepts of the biosphere and the noosphere are vastly different in both theoretical systems.

Vernadsky's and Teilhard's different interpretations of the biosphere and the noosphere concepts can be said to be connected with two divergent properties. Firstly, they had different theoretical premises, in that Teilhard connected the appearance and future development of the human consciousness with the concept of dichotomous matter, while Vernadsky aimed to place humankind into the geological history pointing out the impassable border between living and inert substances. Lastly the differing scientific experience of both theoreticians caused vastly contrasting approaches.

Teilhard de Chardin and Vernadsky made the same principle methodological error, which allowed them to go far beyond the explanatory possibilities of the basic statements of their theories: a certain phenomenon (process) which exists on Earth is analogically extrapolated either in time or in space (or, even, in a spaceless-timeless domain) without any convincing grounds. „We have seen and admitted that evolution is an ascent towards consciousness" - an empirical generalisation. „Therefore", according to Teilhard (1961, p. 258), evolution „should culminate forwards in some sort of supreme consciousness". Even if one accepts that the evolutionary process is a straight line leading to human consciousness, this does not imply that the process will inevitably go further, for human consciousness may be the highest form of reason. Vernadsky also takes the same methodological liberty. He would agree with the first part of Teilhard's passage quoted above, but Vernadsky makes different predictions based on the same statement. The human mind will not result in any higher spiritual entity, but will extend to the limits of the whole biosphere taking under its control all biospheric processes. It is clear that the same methodological liberty allowed Vernadsky and Teilhard de Chardin to pose different explanations based on similar empirical generalisations.

Appendix Table N1: *The Common Points in the Theories of the Biosphere and Noosphere of P. Teilhard de Chardin and V. Vernadsky.*

Teilhard de Chardin	*Vernadsky*
1. The Universe is deeply atomised.	1. The atomic level is the characteristic horizon of exploration in the works of Vernadsky.
2. The Universe and the terrestrial biosphere are seen in the perspective of their wholeness.	2. The biosphere as a whole represents the structure of the Universe and must be seen as an inseparable part of it.
3. The occurrence of terrestrial life is only a local manifestation of a universal cosmic process.	3. „The creatures of Earth are the result of a complex cosmic process. They are an essential and lawful part of a perfectly organised cosmic process, in which, as we know, nothing is accidental" (Vernadsky, 1994, p. 319).
4. Consciousness is a cosmic property.	4. Thought is a planetary and cosmic phenomenon.
5. The pre-biosphere occurs from the very beginning as an interconnected system. The living film of Earth was the surface of organised totality from the beginning.	5. Life appears from the very beginning in the form of the biosphere. All biogeochemical functions must be fulfilled from the very beginning.
6. Teilhard tried to adopt the space-time theory of physics to the biosphere theory.	6. Vernadsky created a theory of biological space-time.
7. Molecular asymmetry is taken as a fundamental property of living matter.	7. Dissymmetry is the characteristic feature of living matter.
8. „The self-organising effort of matter culminates in society as capable of reflection" (Teilhard, 1961, p. 107).	8. Organisation is characteristic feature of the biosphere. Human society is a functional part of this process.
9. The living matter of the Earth shows the properties of a gigantic organism.	9. The biosphere is a self-organising and self-regulating system, which shows some important properties of a living organism.
10. Evolution has an axis, a direction. This direction is indicated by the growth of mind, by the development of a nervous system, by cephalization.	10. Directedness is a characteristic feature of evolution. One of the empirical generalisations which shows the direction of evolution is the so-called Dana principle (cephalization).
11. A relatively irreversible evolution transforms itself into an absolutely irreversible evolution.	11. The evolutionary process occurs in an irreversible time continuum and is irreversible from the very beginning.
12. „To us, in our brief span of life, falls the honour and good fortune of coinciding with a critical change of the noosphere" (Teilhard, 1961, pp. 213-214).	12. „We are living in a special time in the history of our planet, in the psychozoic era, when the new state of the biosphere, the noosphere, is created" (Vernadsky, 1965, p. 270).
13. The shape of Earth is a very significant constant value in evolution.	13. Fundamental features of living matter are determined by the shape and dimensions of our planet.
14. The idea of the fundamental importance of reconciliation of mankind is stressed.	14. The idea of the fundamental importance of reconciliation is clearly expressed.

15. „... Is not modern totalitarianism really the distortion of something magnificent, and thus quite near to the truth?" (Teilhard, 1961, p. 257).

15. „The principles of bolshevism are sound principles" (Vernadsky, 1993, p. 207).[15]

16. The way of prediction: the evolution is a scaling of consciousness, hence evolution must have a culmination in some paramount consciousness.

16. The way of prediction: the appearance of human thought is result of the whole terrestrial evolution, hence the further evolution of the biosphere into the noosphere is inevitable and the noosphere will exist forever.

17. Once appeared, consciousness cannot disappear. It cannot disappear even in case of a cosmic catastrophe.

17. Once appeared, scientific thought cannot disappear. The civilisation of 'cultured mankind' cannot fall into decay.

18. Science plays a significant role in the noosphere.

18. Science plays a leading role in the noosphere.

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[15] One can also find the quotations of Vernadsky and Teilhard exposing their anti-totalitarian views. Yet the dangerous quotations above show that every exaggerated abstract social model has its dark sides.

Table N2: Differences between the Biosphere and Noosphere Theories of P. Teilhard de Chardin and V. Vernadsky

1. There is no clearly definable border-line between living and non-living substances.	1. There is an impassable energetic-spatial-temporal border between the two states of matter: living and non-living. Two words (living and non-living) are connected only by the biogenic flow of atoms.
2. There is a zone of 'subliving'. A virus is an example of a transitional form between the molecule and the cell.	2. Transitional forms between living and inert natural bodies are impassable. A virus should be classified either as a living organism or as an inert natural body.
3. The biosphere is an aggregate of terrestrial living organisms. It is a film on the Earth's surface.	3. The biosphere is a geological stratum and a self-regulating system including both living organism and their inert environment.
4. Abiogenesis is possible. Molecular dissymmetry is an argument in favour of this hypothesis.	4. Abiogenesis is impossible. Molecular dissymmetry is an argument in favour of this empirical generalisation.
5. Evolution leads to the appearance of a psychic state corresponding to the size of Earth.	5. This concept was alien to Vernadsky.
6. Geogenesis is transformed into biogenesis at certain point in time in the development of Earth.	6. Geological evolution of Earth is driven by the evolution of living matter.
7. The noosphere is said to be a cogitative layer of the Earth. It is a transitional state between non-reflective life and the Omega point. The last stage of the noosphere evolution is tied up with the death of Earth. The noosphere is a „one more envelope" around and over the biosphere.	7. The noosphere is the last stage of the evolution of the biosphere. The noosphere is the aim in itself. There are no „psychic centres" of the noosphere. The scientific thought creating the noosphere is a function of the biosphere and its most powerful geological force. The noosphere and the biosphere coincide from the geological viewpoint.
8. Noogenesis is aimed at a psychic centre (the Omega-Point), which transcends space and time.	8. The enigma of life and intelligence is tied up with the peculiar space-time of living matter.
9. The development of the noosphere precedes the 'splitting' of evolution: the separation of intelligence from its material matrix.	9. The idea of the separation of matter and intelligent life is unthinkable in the theoretical world of Vernadsky.
10. „The very centre of our consciousness, deeper than all its radii; that is the essence which Omega, if it is to be truly Omega, must reclaim" (Teilhard de Chardin, 1961, p. 261).	10. There is no super-terrestrial conductor in Vernadsky's theory.
11. Irreversibility and evolution are characteristic features of the Universe.	11. Irreversibility and evolution are intrinsic only to the matter.
12. The concept of Teilhard de Chardin is eurocentric.	12. There are no grounds for preferring European culture in comparison to other cultural traditions.
13. Not only the 'exterior' of life is atomised, but also the 'interior'.	13. In the theoretical system of Vernadsky, a property 'to be alive' cannot be atomised.
14. Teilhard de Chardin proclaims the similarity of science and religion.	14. Vernadsky shows an essential difference between science, philosophy and religion.
15. The unity of the biosphere is simply proclaimed.	15. The unity of the biosphere is biogeochemically argued.

3.2. *THE BIOSPHERE-THEORY OF V.I. VERNADSKY AND THE GAIA-THEORY OF JAMES LOVELOCK: A COMPARATIVE ANALYSIS OF THE TWO THEORIES AND TRADITIONS*

3.2.1. *Introduction*

Some comparative investigations were already made into the theoretical views of the contemporary English chemist, geophysiologist and inventor James Lovelock, and Vladimir Vernadsky (Serafin, 1987; Ghilarov, 1994, 1995; Margulis & Sagan, 1995; Grinevald, 1996; Löther 1998). However, there still remain, in this respect, more questions than answers. The main concern of this chapter revolves around the question posed by Jacques Grinevald (1996, p. 47): „What is the difference between Gaia and the biosphere?"

The question is partially connected with the important problem of the lack novelty of Lovelock's Gaia theory in relation to Vernadsky's biosphere theory. The ideas of Lovelock were ignored in the West at the outset, but later induced a big discussion and are often seen as a kind of revolutionary theory. Elisabet Sahtouris (1995) reports that Lovelock shocked the world of science by suggesting that geological environment is an active creation of living things. Many of the representatives of the Vernadskian tradition in the East were astonished at the boom around the Gaia-hypothesis. This topic has been extensively reviewed by the followers of the Vernadskian tradition. By way of example, in the general theoretical book written by Russian biospherologist and scientific historian Kolchinskij (1990, p. 48), we read:

> „Vernadsky's claim that life creates for itself necessary environmental conditions by transforming the atmosphere, has become a truism in recent years in our country... The idea that to a great extent life determines the characteristic features of the environment has been established in Russian scientific literature long before the Gaia hypothesis was proposed by J. Lovelock in the 70's... It is thanks to Vernadsky's services, and not Lovelock's, that this idea was first proven from all points of view".

Another representative of Vernadskian tradition A. Yanshin (1997, p. 16) goes further and states that „Lovelock's conclusions are identical to those made by V. I. Vernadsky as early as in the 1920s". The similar position is expressed in some other articles and books of Vernadskians (Yanshina, 1996).

At the same time, I do not know of any works where the theories of Lovelock and Vernadsky were compared and analysed in detail. So I shall be concerning myself precisely with this in this chapter. I will examine the basic statements of the Gaia theory as represented in the works of Lovelock and other advocates of his theory. I then compare these statements with those of Vernadsky. In comparing the two theories, I look only at the most general basic statements due to the incomparability of the scientific data available now and at Vernadsky's time of writing.

3.2.2. *The Biogenic Character of the Earth's Atmosphere*

One of the first steps toward the construction of Gaia-theory, which Lovelock himself sees as innovative, was a conclusion on the biogenic character of the Earth's atmosphere. Lovelock wrote (1989a, p. 7):

> „Our findings and conclusions were, of course, very much out of step with conventional geochemical wisdom in the mid-sixties. With some exceptions, notably Rubey,

> Hutchinson, Bates, and Nicolet, most geochemists regarded the atmosphere as an end-product of planetary out-gassing and held that subsequent reactions by abiological processes had determined its present state".

Ignorant of Vernadsky's works Lovelock supported Hutchinson's biogenic vision of the Earth atmosphere's origin. Yet, remarkably, it was Hutchinson who was influenced by the biogeochemical ideas of Vernadsky (Kingsland, 1995) and who stated that it is essentially Vernadsky's concept of the biosphere, developed about 50 years after Suess wrote, that we accept today (Hutchinson, 1970). The notion of the biogenic character of the atmosphere is one of the important conclusions in the biosphere theory of Vernadsky. In his final book, *The Chemical Structure of the Biosphere of the Earth and of its Environment*, written in the 1940's Vernadsky wrote:

> „It can be affirmed now, that our troposphere is not an astronomical phenomenon, i. e. connected with gravity, but that it is a creation of living matter and that its predominant gaseous masses are of biogenic origin" (1965, p. 215); „...Astronomers, when talking about life, consider only O_2, CO_2 and H_2O. At the same time we see that in the Earth's atmospheres not only these gases but also H_2, N_2, H_2S and hydrocarbons are biogenic in dominant quantities" (1965, p. 229).

Vernadsky himself stressed as early as 1912 his partisanship to a theory of biogenic origination for all gases of the biosphere (Vernadsky, 1912, 1965). The production of gases was classified by Vernadsky as biogenic processes of the first and of the second kind. Biogenic processes of the first kind are an immediate manifestation of life connected with respiration, eating, etc. Biogenic processes of the second kind are connected with the destruction of biogenic and bioinert rocks and manifest themselves, for example, in such phenomena as metamorphism and volcanism (Vernadsky, 1965) [compare with weathering of rocks in Lovelock's concept (Lovelock, 1989a)]. Vernadsky clearly stated the biogenic character of the atmosphere and distinguished the direct and indirect processes of its gases biogenic production.

3.2.3. *The Biosphere as a Dynamic self-regulating System*

However, it is not the inference of the atmosphere's biogenic character that is most characteristic of the Gaia-theory. The most revolutionary idea of Lovelock is that of Earth as a system where biota (living matter) plays an active role. In this system, biota is seen as creating and controlling („homeostating") its abiotic (inert) environment (Watson, 1988). In other words, it is the assertion that the biosphere is a self-regulating system - Gaia (Grinevald, 1996). Lovelock phrases it in the following way:

> „We have since defined Gaia as a complex entity involving the Earth's biosphere, atmosphere, oceans, and soil; the totality constituting a feedback or cybernetic system which seeks an optimal physical and chemical environment for life on this planet. The maintenance of relatively constant conditions by active control may be conveniently described by the term 'homeostasis' " (Lovelock, 1989a, p.11).
>
> „Through Gaia theory, I see the Earth and the life it bears as a system, a system that has a capacity to regulate the temperature and the composition of the Earth's surface and to keep it comfortable for living organisms" (Lovelock, 1989b, p. 31).

Some remarks about the terminological inconsistencies of the quoted passages should be made. Seen from the Vernadskian point of view the definition would be incorrect. The atmosphere of our planet belongs to the biosphere. Vernadsky always maintained that the troposphere is a biogenic gaseous component of the biosphere and consists of three parts: the supraterrestrial troposphere, the subterranean troposphere and the submarine troposphere (Vernadsky, 1965). At the same time the biosphere cannot exceed the limits of the field of life existence. This means that there is a conditional atmospheric limit of the biosphere within the atmosphere. Vernadsky's works show this border somewhere on the border between the troposphere and the stratosphere. Lovelock uses the term „atmosphere" in a similar sense to Vernadsky's „troposphere" (Lovelock, 1989a; Margulis, 1988). Vernadsky often stressed that the oceans belong in their entirety, including the ocean floors, to the biosphere. The soil is a classic example of biospherical processing in the works of Vernadsky. Therefore, we cannot say that Gaia is simply made up of „biosphere" + „atmosphere" + „ocean" + „soil", because all these regions are already included in the processes of the biosphere. Nor is it fully correct, in traditional Vernadskian terms, to say that „the biota and the biosphere taken together form part but not all of Gaia" as Lovelock does (Lovelock, 1989b, p. 19), since the biota („living matter" according to Vernadskian terminology) is by definition included in the biosphere (Vassoyevich, Ivanov, 1977).

Considering the theoretical concept expressed in the quotation above, we must note that to this extent there are no principle differences between the two theories. Lovelock came to his Gaia, first of all, analysing the composition of the Earth's atmosphere. The same way of thinking we find in the works of Vernadsky (1965, p. 238):

> „All basic gases of the troposphere and of the higher gaseous envelopes - N_2, O_2, CO_2, H_2S, CH_4, etc., - are produced and quantitatively balanced by the total activity of living matter. Their composure and proportionality are quantitatively invariable over geological time...". Vernadsky demonstrates that „life, i.e. living matter creates the troposphere and constantly maintains it about the certain dynamic equilibrium".

It seems astonishing that Vernadsky (1965, p. 229) went even further in his time and stated that „the gases, which are biogenic on Earth, will also be biogenic on the other planets, since the thermodynamic conditions do not hinder them". As Lovelock later does, he connected the chemical and physical activity of life with the reduction of entropy (Vernadsky, 1965; Lovelock, 1989a) and after he had examined the relevant data available at the time he proposed that the presence of life on Mars and Venus can be proved by the analysis of their atmospheres.

Vernadsky makes a conclusion about the oceans in relation similar to the one about the atmosphere. Having analysed the chemical compounds of the ocean he stated: „It is significant that it [the ocean] is throughout penetrated by living matter, which (directly or indirectly) completely determines all chemical properties of the ocean. These are the most powerful manifestation of living matter on our planet" (Vernadsky, 1965, p. 220). One of Vernadsky's first assertions about the regulative function of life in relation to the ocean was made in 1923 (Vernadsky, 1923).

Vernadsky does not confine himself to conclusions about just the oceans or the atmosphere. He generalises his statements to include the biosphere as a whole: „Every organism is a centre of a free energy. In its totality, living matter transforms completely the domain of life - the biosphere" (Vernadsky, 1965, p. 232) and „determines all basic chemical regularities of the biosphere" (Vernadsky, 1965, p. 236). His final conclusion appears to conform to the main thesis of J. Lovelock: „It looks as if life, living matter were creating for itself the domain of life" (Vernadsky, 1965, p. 241).

Thus, in the 1930's and 40's Vernadsky was already aware that living matter creates the basic parameters of its environment and keeps them around certain dynamic equilibria.

Such a view of the biosphere is held by some contemporary representatives of Vernadskian tradition (Kolchinskij, 1990). The disciples of Vernadsky, N. Vassoyevich and A. Ivanov (1977), also define the biosphere as a self-regulating system. A. Perelman (1986) stated that the biosphere as an information processing system is characterised by the positive and negative feedback loops. In the collective monograph „*The Contemporary Problems of Preserving and Researching the Biosphere*", based on the theory of Vernadsky, we find a definition of the biosphere as an integrated, non-linear, open, self-organising system possessing homeostatic properties (Krasnogorskaja, 1992). Thus, we can, so far, find no principle differences between the basic assertions of Vernadsky and the Gaia theories.

At the same time, one should be aware that the advocates of Gaia posed the problem of the homeostatic properties of the biosphere more precisely than Vernadsky himself based on data collected in the 50 years after Vernadsky wrote down his conclusions. Vernadsky was in no position to make a numerical model of the biosphere comparable with the „*daisy world model*" and other models of Gaia (Schellnhuber, Wenzel, 1998). In the Vernadskian tradition mathematical modelling of the biosphere was pioneered by Moiseev with colleagues (e.g., Moiseev et al., 1985).

3.2.4. *Earth as a Living Organism*

3.2.4.1. *Vernadsky and Lovelock on the Subject*

The problem of the differences between the theories of Lovelock and Vernadsky can be approached as Lovelock does so himself in his recent article on the topic. Lovelock talks about the „traditional" and „liberal" views in the history of the Earth sciences. The „traditional" approach sees the Earth as having a capacity „to regulate itself and to keep cool when things are changing adversely", i.e. to keep homeostasis. He concludes: „This then is the first tradition, that sees the Earth as a living organism" (Lovelock, 1996, p. 15-16). Lovelock ascribes himself to this „traditional" view.

Lovelock defines Earth as a living organism, first of all, because of its homeostatic properties. But he draws also some other analogies to show how close the concept of Gaia is linked with the concept of life. Perhaps the most illustrative is his morphological *redwood tree - argument*: „The tree undoubtedly is alive, yet 99 percent is dead" (Lovelock, 1989b, p. 27). Dead wood of a tree can be compared with the apparently inanimate rocks of the Earth.

It should be noted that not all advocates of the Gaia-theory share this opinion. For example, one of the champions of the Gaia-theory, the cell biologist and geophysiologist Lynn Margulis, writes: „I reject Jim's statement 'The Earth is alive'; ...I do not agree with the formulation that says 'Gaia is an organism' " (Margulis, 1996, p. 54).

Lovelock calls the second approach „liberal" and writes: „Co-evolutionists accept that organisms may change the composition of the material world but they do not accept that life has a constructive influence by which organisms alter the material world in a way that affects their own selection." And in this context he poses a question which is central to this discussion and is analysed below: „...I have never been clear whether Vernadsky was of this liberal co-evolutional middle view of the Earth or whether he subscribed to the first traditional view" (Lovelock, 1996, p. 16).

Our answer, which is argued below, is, in short, that: Vernadsky would, without doubt, have subscribed to the „traditional" view in the sense that he would have accepted that the biosphere has a capacity to regulate itself and to maintain homeostasis. However, Vernadsky never used the term „super-organism" or „living organism" or „living natural body" in relation to the biosphere because he was convinced that the biosphere is not a living, but a bioinert natural body.

Lovelock defines the capacity of the Earth to regulate itself as „homeostasis". Vernadsky would clearly have agreed with this term. He often pointed out that the biosphere executes a regulative function in relation to the atmosphere, the ocean, the soil, etc. The term *homeostasis* is often used in this context by the followers of Vernadsky (Krasnogorskaja, 1992; Lapo, 1987a). What neither Vernadsky nor the majority of his followers would accept is Lovelock's claim that the Earth is a living organism because it shows homeostatic properties. It is evidently not sufficient for defining Earth as a living organism.

Describing the biosphere biogeochemically, Vernadsky uses the terms „living matter", „inert matter", „bioinert matter" and „biogenic matter". In order to describe the peculiar place of the biosphere on this scale he applies the term „bioinert natural body":

> „In the biosphere, apart from the living and inert natural bodies, a great part is played by their regular structures, by heterogeneous natural bodies, for example, soils, silt, surface water, the biosphere itself, etc.; they are constituted by coexisting living and inert natural bodies forming complicated bioinert structures. I shall call these complicated natural bodies 'bioinert natural bodies'. The biosphere itself is a complex planetary bioinert natural body" (Vernadsky, 1991, p. 18; or for a different translation of terminology, see: Vernadsky, 1997, p. 27-28).

Vassoyevich and Ivanov (1977) modernised Vernadsky's terminology and defined the biosphere as a bioinert system, i.e. a system formed by the two mutually stipulated basic subsystems: inert and living.

An original interpretation of Vernadsky's concept was proposed by Moiseev et al. (1985). He defines „organism" as a system which has certain goals and the abilities to follow these goals. According to Moiseev the biosphere is actually not yet an organism, but will become one once it turns into the *noosphere*.

The use of Hutton's term „super-organism" requires an exhaustive definition of organism, a task which was hardly accomplished in Vernadsky's biogeochemical terminology. This problem could be approached, for example, from the morphological-physiological perspective, but not by Vernadsky who stated that „the morphologically and physiologically exact visage of the living nature, and particularly of the living individuals, appears in biogeochemistry as an auxiliary concept for studying life phenomena" (Vernadsky, 1997, p. 204-205). He therefore, totally escapes the terms „super-organism" and „organism" with regard to the biosphere. At the same time, in trying to get away from a pure mechanistic view of the biosphere, Vernadsky defines the biosphere as an „organisation" referring to A. N. Whitehead (1861-1947), who understood the term „organisation" as any unit which determines the eventual character and integration of its component parts. "Organisation" is opposed here to "mechanism", in the sense that "a mechanism is entirely determined" (Abram, p. 242) The structure of the biosphere is described as a dynamic equilibrium: „No single point of this system takes a certain place in it during the geological time. All points oscillate about a certain place" (Vernadsky, 1965, p. 236).

Thus, the biosphere is defined by Vernadsky as an „organisation" and as a „bioinert system", but not as a living organism. According to Vernadsky there are some important differences which distinguish the „living natural bodies" from „inert natural bodies". He finds about 12 crucial distinctions, which clearly differentiate the inert and living bodies of the biosphere (see 2.3.5.). The basic difference is connected with the spatial-temporal and energetic separation of living bodies from the environment. The state of space of living matter is characterised, first of all, by the notion of spatial-temporal dissymmetry, i.e. temporal irreversibility and non-identity of the leftness and the rightness in living organisms' state of space. Thus, although living organisms also include the inert parts in their structures and although the inert parts can dwarf the living parts themselves they are the quasi-bioinert bodies, because of the two basic reasons: (1) the bioinert and really living bodies show different spatial-temporal-energetic characteristics; (2) in bioinert systems, the regularities of living and inert processes interact, although living matter plays the leading role. Accordingly, Vernadsky took the biosphere for a self-regulating system, but merely defined it as a *bioinert system* and not as a living organism.

One can give another comparative dimension to this problem by suggesting that if the Earth/Gaia/Biosphere is a living organism, then it must be comparable to other living beings (Sahtouris, 1996). The task can be approached from different angles. For example, Sahtouris based her view on the concept of Vernadsky's biogeochemical cycles, apparently without knowing his own definition of the biosphere as a bioinert system. Resorting to the autopoetic features of Earth in accordance with the theoretical claims of Maturana and Varela she proposed a concept of Gaia as a living super-organism (Sahtouris, 1996).

One can also approach this question from a rather morphological viewpoint, something Vernadsky defined as „secondary" in his theory of biogeochemistry. It was along these lines, though, that a younger contemporary of Vernadsky, V. N. Beklemishev (1890-1962), created a detailed theory of the biosphere as a living system. The attention of historians of science had already been drawn to the necessity of a comparative analysis of these two theories (Svetlov, 1994).

3.2.4.2. *Beklemishev's Theory of the Biosphere as a Morphoprocess*

Beklemishev was an outstanding Russian zoologist, ecologist, and theoretician of biology. He can be ranked among the immediate predecessors of geophysiology. Beklemishev (1994, p. 61) wrote about the biosphere: „...The living crust, stretched over the stony globe, manifests the main characteristics of organisation: a constant maintenance of the typical forms and relationships of the whole by the constant changing of parts, a close *physiological* [our italics - *auth.*] coordination of all heterogeneous components which create the conditions necessary for everyone's existence". In order to define the morphology and physiology of the biosphere, Beklemishev proposed the terms *symmorphology* [compare the term *biogeomorphology* as proposed by Krumbein (1996)] and *symphysiology*.

In his most known book *„The Fundamentals of the Comparative Anatomy of Invertebrates"*, which has been translated into English and German several times, he endeavoured to show a morphological unity of the living world. Perhaps, partially based on Vernadsky's notion of the biosphere and on his own morphological and ecological investigations, Beklemishev expounded an original theory of the biosphere (he also used the term „Geomerida", coined by K. D. Starinkevich) - the hierarchically structured living wholeness on the Earth's surface - and expressed his views mainly in the book *„The Methodology of Systematics“* written in 1928 (i.e. two years later than *„The Biosphere“* of Vernadsky) but published only in 1994, and in the article *„On the General Principles of the Organisation of Life“* (1964). Beklemishev (1964, p. 26), as well as Vernadsky and Lovelock, came to the conclusion that the processing of matter in the biosphere is controlled by life:

> „Taking place in the biosphere, the process of rotation of matter, energy and specimens is carried out by all living organisms within the biosphere and is stabilised to the degree which guarantees the continued existence of life on the Earth. In other words, life is organised on the planetary scale. All living beings are parts of one whole. This whole is the great sum-total of all living beings, the living cover of the Earth“.

By his mostly morphological way of thinking, he came to the conclusion that the atmosphere is a non-living part of the living cover of the Earth and that it is regulated and structured by the inherent living matter (Beklemishev, 1964).

Beklemishev also took as a basis for his concept a notion of „organisation“ and operated with the terms „morphoprocess“, „individuality“ and „system“ to come to a definition of the biosphere. He did not accept Vernadsky's classification of natural systems (living, inert, bioinert) however, nor his definition of bioinert systems. All organisms are composed by living and non-living components. The structure of natural soils (classic example of a bioinert system) is created, developed and maintained by the living components controlling their inert environment and can be compared to the structure of living tissue.

The ultimate object of biological systematics is not a "natural body", which is basic to the theory of Vernadsky, but a *morphoprocess*. The concept of a morphoprocess involves regular growth and change of the identifiable lasting form. In the other words, life as a morphoprocess is characterised, from one hand, as a form lasting in the flow of changes, but, from the other hand, this 'lasting form' is in the regular growth and change and is seen as a self-organising process. Morphoprocess is a dynamic form of organisation of matter and not an organism in the trivial sense. It is not necessarily interrupted when an individual disintegrates. The global morphoprocess is a totality of living matter of our planet.

According to Beklemishev (1994, p. 54), there is no life and death; there is more or less organisation. The concept of the ***individuality of morphoprocess*** help Beklemishev to distinct between "more or less organisation". It expresses a specific degree of organisation of biological phenomenon. Generally speaking, individuality indicates maintenance of some crucial characteristics of a system amid the flow of changes. In the case of fruitful application of this category, i.e. when a system is sufficiently complex and its crucial characteristics are controlled and stabilised, we say that we are dealing with a high degree of individuality, i.e. with a living entity. I will point out the following important characteristics in order to present a more precise description of the degree of individuality of the morphoprocess: **functional harmony**, **rhythm**, and **morphogenetical secludedness.**[16]

The first important indicator of the individuality of a living system is so called ***relational functional harmony*** of this system. Most biological systems consist of parts

[16] Below you find *my* reconstruction and interpretation of Beklemishev's theory. There are also another viewpoints on the subject possible. I do not subtilize the discussion here, because otherwise I would need to write another book.

which, in their turn, can be highly individualised and perceive their own interests. As Beklemishev (1994, p. 57) puts it: „*Every organism is in the nature of semi-parasitic, semi-mutualistic community; life of the wholeness is based on the conflict and destruction of the parts; the world 'lies in the evil*". [compare: all organisms, apart from the single bacterial cell, are superorganisms in that they are the products of symbiosis, which is seen as a new *individuality* (Margulis, Guerrero & Bunyard, 1996)]. The better every living part supports the development of the whole system, and the better the whole supports the functions of individual morphoprocesses , the higher is the "*degree of mutuality*" and, hence, the level of functional harmony a system. A high degree of mutuality does not automatically point out the high level of individuality, but is its necessary prerequisite.

Most biological objects consist of parts which, in their turn, can possess a certain degree of individuality, but can be also very simply organised like water in the colloids of plasma, hair and so on. This scale brings us to the idea of the "*depth of organisation*". Note, that "depth of organisation" alone says nothing about the degree of functional harmony, but it points out that there is something to be harmonised.

The third important characteristics of functional harmony is *the number of "specific adjustments*" which stabilise and control (harmonise) a living system (e. g., homeostatic mechanisms). The higher a number of specific adjustments of living system, the higher a degree of functional stability and, hence, the higher a degree of individuality.

A biosystem has to be seen not only as an individual, but also as a part of the morphoprocess. From the standpoint of ***rhythm***, all morphoprocesses can be considered either *periodic* or *aperiodic*. Most morphoprocesses are periodic, e.g. bacterial division. An aperiodic morphoprocess appears when the rhythms of the constituent parts of a morphoprocess are not co-ordinated. The presence of a common rhythm is an important criterion of individuality. It is important to distinguish between complex combinations of rhythms and absolute arrhythmia.

Periodic morphoprocesses can be classified according to their 'terminality' into *cyclic* and *terminal-cyclic*.

Cyclic morphoprocesses are those in which all parts would stay alive despite the destruction of the whole and would take part in a further morphoprocess.

Terminal-cyclic morphoprocesses take place in the cases when mortal soma is clearly separated from transmitting genes propagative units. Terminality in this case points to the high degree of individuality and is seen as a contradiction between the individuality of an organism and its striving for an infinite size: "Only in the presence of a clearly-expressed individuality, characterised by the strict expression of a plan, does unlimited growth collide with a barrier requiring the necessity of fission" (Beklemishev, 1994, p. 65)

Aperiodic morphoprocesses can be classified into *terminal* and *indefinitely lasting* ones. Both cases indicate a low degree of individuality: an excessive subordination of the parts to the whole in the first case and a weak co-ordination in the second case.

Beklemishev also pointed out that morphoprocesses can as well be classified from the viewpoint of their ***morphogenetical secludedness***:

- closed, if they allow no significantly modifying morphogenetical input during the life cycle (*ideal case*);
- open at a certain moment for certain components: all organisms multiplying sexually;
- open during most periods of the life cycle (*Mycetozoa*);

- open during the whole period of their existence (cyanobacteria, biofilms, bioceonoses).

These four types of the morphoprocess represent different levels of individuality. Roughly speaking, the more closed is a morphoprocess, the more independent it is from the environment and the higher the degree of its individuality[17] (Beklemishev, 1994, pp. 68-69; 1964, p. 33).

On the basis of comparative analysis one can come to the conclusion that the Biosphere shows all important properties of a morphoprocess and, hence, of a living system:

1. The Biosphere is a semi-mutualistic community of the biosystems which despite of their independence compose a harmonised, self-regulating system demonstrating "close *physiological* [our italics] coordination of parts" (Beklemishev, 1994, p. 61);

It shows:

2. certain physiological and morphological stability of the whole by the constant rotation of the parts;
3. close functional co-ordination of cyclic irreversible highly individualised morphoprocesses: a degree of functional harmony unimaginable in the inert world;
4. The biosphere consist of the living and non-living parts as every living system. Living parts are composed, in their turn, by the living parts of the lower order (but can be, nevertheless, of higher individuality). In that sense the biosphere is a morphoprocess of the highest order.
5. At the same time, the biosphere is a faintly individualised organism: being seen as a morphoprocess it is constantly opened and arrhythmic. The low grade of individuality of the biosphere is a cost of its high complexity and differs the biosphere from the 'trivial' organisms of Linnaean system. The degree of individuality of the biosphere is nevertheless comparable with that of some lowest biosystems.

Methodologically Beklemishev and Vernadsky can be seen as representing opposite poles in their interpretation of the biosphere. Beklemishev saw the biosphere, first of all, as a morphoprocess, i.e. morphologically, while Vernadsky interpreted the biosphere biogeochemically as the flow of chemical elements. At the same time, one finds in Beklemishev's theory elements of the physiological approach and Vernadsky's theory is partially morphological. Most approaches to the biosphere (Gaia) can be located within the spectrum „Beklemishev - Vernadsky".

3.2.5. *Evolution of the Biosphere*

Lovelock (1989b, p. 19) himself insists on the difference between the terms „Gaia" and „the biosphere":

> „The name of the living planet, Gaia, is not a synonym for the biosphere. The biosphere is defined as that part of the Earth where living things normally exist...
> Specifically, the Gaia hypothesis said that the temperature, oxidation state, acidity, and certain aspects of the rocks and waters are at any time kept constant, and that this

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[17] The similar principle can be constructed also for the *physiological* secludedness (see: Beklemishev, 1964).

> homeostasis is maintained by active feedback processes operated automatically and unconsciously by the biota. ...Life and its environment are so closely coupled that evolution concerns Gaia, not the organisms or the environment taken separately".

As we have seen, the biosphere was also seen by Vernadsky as a self-regulating system. The thesis on the evolution of the biosphere had also been clearly stated by Vernadsky, who claimed that the biosphere as a whole possesses its own evolutionary regularities.

> „Incessantly, during all the geological time, the evolutionary process of the living matter embraced the whole biosphere and, in various ways, influenced (though less distinctly) its inert natural bodies. This alone allows us and makes us speak about the *evolutionary process of the biosphere itself* taking place in the inert mass of its abiotic and live natural bodies, evidently changing within the course of the geological time" (Vernadsky, 1997, p. 30).

That is why the biosphere develops the functions of living matter which, in turn, increase the level of complexity and introduce a degree of self-regulation and stability to the biosphere. The scientists of Vernadskian tradition, Vassoyevich and Ivanov (1977, p. 87), wrote in this connection:

> „V. I. Vernadsky considered the evolution of the organic world to be a lawful manifestation of the *evolution of the planetarily organised system - the biosphere*, in which all living things interact with the inert [environment]. He regarded the evolution of the biosphere as its alteration and complication as a whole".

One of the methods for expressing these „interests" of the biosphere is by intensifying and making more complex the biogenic migration of atoms. The evolution that satisfies these „interests" turns out to be a multi-stage process and goes according to the biogeochemical principles of Vernadsky. Lovelock does not discusses the problem of the biosphere evolution on this plane. The evolution of the biosphere has been broadly discussed and from the various perspectives within the terms of Vernadskian tradition (Kamshilov, 1979; Budyko, 1986; Kolchinskij, 1989, 1990). The detailed comparative analysis of the evolutionary views of the two theories is a topic for a special contribution.

3.1.6. *The Place of Modern Science and Technology in the Evolution of the Biosphere or Gaia*

The Weltanschauung of the Modern Age proceeds from the concept of opposing „nature" and „man". The roots of this view originate from the Descartes' notion of nature, who contrasted *res cogitance* and *res* extensa (Hösle, 1991). The industrial revolution made deeper a rift natural-artificial or „nature" versus „technology". A cliché evolved about human activity as about something „unnatural".

In the first half of the 20th century we find the attempts to reconcile „man" and „nature" and to understand human thought as a regular part of nature. Vernadsky and Teilhard de Chardin created the global theories, in which the human mind is represented as a lawful product of the biospherical evolution. In both cases the appearance of thought (in any form) is seen as the regular outcome of the planetary (cosmic) evolutionary process. This approach is known as teleology (Barrow, Tipler, 1986).

Arguments of Vernadsky are based on his theory of the biosphere. According to him the first and second biogeochemical principles (BGCP), biogenic migration of atoms in the biosphere tends toward the limit of its potential manifestation (Krumbein, Lapo, 1996). The biosphere is said to be home to species and forms of *organisation* which accelerate the biologically controlled migration of atoms. This means that the evolution of the biosphere is *directional*. The evolution of the biosphere carries on in the direction of the increasing biogenic migration of atoms. The appearance of human reason has prompted a so called biogenic migration of the third kind which has powerfully accelerated the processes of atomic migration (Vernadsky, 1965) and, hence, human activity lies in the general trend of the biosphere's development.

Assuming the first and second BGCP's they are followed by the indication that the biosphere tends towards a maximum manifestation of its kinetic energy and that the forms of organisation and the species, which satisfy this aspiration, should occur in the biosphere. Scientific thought helps discover new sources of energy and optimises the modes of energy use.

The third principle concerning the directionality of the biosphere's evolution Vernadsky refers to the *empirical generalisation of D.-D. Dana* [1813-1895]. This generalisation shows that the evolution of the biosphere is connected with the development of a central nervous system in some species (*cephalization*) (Vernadsky, 1997). Human reason, and the scientific thought that comes with it, are the results of a natural process of cephalization.

This way Vernadsky (1997, p. 31) comes to the conclusion that scientific thought and the end products of scientific activity turn out to be a lawful part of a natural landscape and „an inevitable manifestation of a great natural process having lasted in a regular way for at least two billions of years".

In this respect, Lovelock's and Vernadsky's way of thinking have some similarities. Lovelock recognises that humankind has increased the carbon cycle by 20 per cent, sulphur cycle by over 100 per cent. It is known now that the manganese cycle was increased by even over 1000 per cent. Nevertheless he states that „in a Gaian world our species with its technology is simply an inevitable part of the natural scene" (Lovelock, 1989a, p.127). By way of example Lovelock argues that the most significant example of „anti-natural" human activity, namely pollution, is one of the trivial natural phenomena.

Nevertheless, it is evident that one can see some methodological differences between the approaches of the two scientists. Vernadsky constructs his sequence of thoughts in the following way (I shall modernise his language): science and based on science technology are natural because their appearance is regular, expected and inevitable, albeit not a fully determined process. This approach can be characterised as a kind of *teleology*. Vernadsky's viewpoint on evolution is close to what Ayala calls *indeterminate natural teleology*: „Indeterminate or nonspecific teleology occurs when the end-state served is not specifically predetermined, but rather is the result of selection of one from among several available alternatives" (Dobzhansky et al., 1977, p. 500). Indeterminate teleology results from a mixture of stochastic and deterministic events. For Vernadsky, who wrote that „the biosphere will transform (in one way or another, sooner or later) into the noosphere" (Vernadsky, 1997, p. 55), the appearance of human reason and scientific thought was such a process.

Yet teleology is a deadly sin for a modern scientist. Lovelock does not accept teleology in connection with Gaia (Lovelock, 1989b) and goes the other way declaring that our technology is an inevitable part of the natural scene because we can point out the *analogies* between human activity and natural processes. The question arising from this approach is: do these analogies of Lovelock not also show that science and technology is a regular product of the natural processes? In other words, when we say

„natural“ does it not mean also „regular“ or „expectable“? We should be able to understand Lovelock's position that the technological manifestations of the humankind are a kind of natural product, but that the appearance of humans (science, technology) is in the first place not a regular (inevitable) process and, hence, we can escape the accusations of teleology. The appearance by chance can also be seen as a natural process.

3.2.7. *The Idea of the „Vital Regions“ of Gaia*

In his book „*Gaia: a new look at life on Earth*“ Lovelock (1989a, p. 127) talks about the three principal characteristics of Gaia: (1) the tendency to keep constant the conditions for all terrestrial life; (2) the presence of vital and redundant organs; (3) that Gaian responses to changes must obey the rules of cybernetics, „where the time constant and the loop gain are important factors“. The only important theoretical statement, which is specific to the Gaia as opposed to the biosphere is the second statement concerning the vital organs.

Lovelock backs up this statement by pointing out the fact, that the regions beyond latitudes 45^0 North and 45^0 South are subject to glaciations. It seems that Gaia can tolerate the loss of these parts of her territory (Lovelock, 1989a). He goes on to propose the hypothesis that glacials are the normal state of our planet and the interglacials represent a temporary failure of regulation (Lovelock, 1989b).

Vernadsky was also very aware of glaciations and analysed them from a biosphere perspective. He writes: „Thus, we see that for the planet taken as a whole glaciation is not a period of coldness. Decisively life developed powerfully on the planet in that time, outside the certain areas of the land and shelfs...“ (Vernadsky, 1965, p. 55). Vernadsky realised that the attempts of the geologists of the day to connect glaciations with the inner processes of the Earth were wrong. He proposed that glaciations should be associated with astrophysical processes and the activity of living matter and that they are the manifestations of a more general phenomenon - namely „pulsation“ of geological processes (Vernadsky, 1965). Man is a creation of one of these critical periods.

Another, spatial, aspect of the global biospherical regularity Vernadsky terms the chemical-physical „heterogeneity“ of the biosphere (Vernadsky, 1965). He proposed that this heterogeneity is determined Earth's the properties as a planet and connected heterogeneity with the relative motionless of the hard substrate of the *geochores* (films of living matter on the land).

The authors could not find any further statements by Vernadsky about both regions of the biosphere, which are important for life and those which are not.

3.2.8. *The Biosphere as a Geological Envelope*

The biosphere was furthermore investigated by Vernadsky and his followers as a geological envelope. This aspect differentiates Vernadsky's approach from that of Lovelock and Beklemishev, who paid little attention to the geological structure of the biosphere and its environment.

One of the most important questions arising from the biosphere as a geological envelope concerns the boundaries of the biosphere and its place in planet Earth's very structure. To define the biosphere, as seen from this angle, Vernadsky introduced two basic principles:

The first principle maintains that *the limits of the biosphere are defined by the presence of life*. The statement represents a necessary, although not satisfactory condition. Various organisms can often be found outside the average limits of the biosphere. Does this mean that the biosphere is represented everywhere, where separate organisms can be detected? To answer this question Vernadsky introduced the term the *field of life resistance*, which extends beyond the *field of the biosphere* (Vernadsky, 1994). The field of life resistance differs from a *field of life existence*, which is defined as connected with the multiplication of organisms. The limits of the biosphere are restricted by the field of life existence (Lapo, 1987b). The disparity between the field of life *existence* and *resistance* is explained by the vertical and horizontal expansion of the biosphere over geological time.

The second principle for defining the limits of the biosphere is phrased by Vernadsky as follows: „The main indication of the biosphere is the participation of living matter in all its processes“ (Vernadsky, 1965, p. 79). The first principle shows the dynamics of living matter, whereas in the second case Vernadsky talks about the dynamics of the inert parts of the biosphere.

However, Vernadsky did not define clearly enough a place of the biosphere between other geological envelopes. A scheme of the relationship between the biosphere and other geospheres as accepted by many of the followers of Vernadskian tradition (Kolchinskij, 1990, Lapo, 1987b) was later proposed by Vassoyevich and Ivanov (Vassoyevich, Ivanov, 1977) (see: 2.3.2.).

3.2.9. *Conclusions*

1. One can distinguish two traditions in the use of the term „biosphere“. In the works of Lovelock and his followers the term biosphere is mostly used for describing the domain where life exists and opposed to the term „Gaia“ as emphasising the self-regulating properties of the Earth. In the works of Vernadsky and many of his followers the term biosphere combines the two meanings: the biosphere as a geological envelope and the biosphere as a self-regulating system. This seems to be an answer to the question: why the term „Gaia“ is so hard settling down in Eastern Europe, while it becomes more and more popular in the West.
2. The insinuations of Lovelock and Vernadsky about the natural character of science and technology have some similarities. At the same time, one has to be aware that their philosophic-methodological starting-points are significantly different.
3. The comparative analysis of the Gaia-theory and Vernadsky's theory of the biosphere shows that some crucial theoretical claims, which are fundamental to the Gaia-theory, had already been stated by Vernadsky as early as in the 1920's and 40's. These include: (1) the biogenic character of the atmosphere; (2) the self-regulating capacity of the biosphere; (3) the evolution of the biosphere as a whole system including both its biotic and abiotic components. Until the advent of the Gaia-theory theoretical investigation into these problems was continued by the followers of Vernadsky.

Some other important theses of Lovelock's Gaia-theory, however, have no direct analogies in the Vernadskian tradition. These include: (1) the thesis that Gaia has „vital organs and a core“; (2) the concept of Gaia as a living organism. On the other hand, in contrast to the advocates of Gaia, Vernadsky and Vernadskians paid a lot of attention to defining the biosphere as a geological envelope.

At the same time, not all defenders of the Gaia theory share the opinion that Earth is a living organism. By way of contrast, there are some authors influenced by Vernadskian thought, who believe there is a problem in the notion of organism in connection with the biosphere-theory.

The comparison of the basic claims of the two theories also shows the domain, where the term „Gaia“ can be properly applied from the viewpoint of the Vernadskians. From this viewpoint the specificity of the term „Gaia“ is, first of all, tied up with the assumption that Earth is a living (super-)organism. Most of the other general claims associated in the modern Western literature with the Gaia-hypothesis can be discussed also in the frame of the biosphere-theory. At the same time, as I have briefly shown, one can also point out the important methodological and philosophic-methodological differences between the two theories. However, this is a theme for a more specialised investigation.

4. Summary

1. Vernadsky attempted to create a theoretical system describing all basic processes of the Earth including biological, geological, social and cultural ones. All parts of this theoretical system are interconnected. I distinguish three basic theoretical units composing this theoretical system:
   (a) The theory of the biosphere and its transition into the noosphere.
   (b) The theory of space-time.
   (c) The general philosophy (theory) of science.

Vernadsky provides each theory with a specific terminology, postulates laws and makes predictions (retrodictions) based on this theory. The three theoretical entities together compose an all-embracing theoretical system which represent the totality of natural, social and cultural processes on Earth as one single planetary process.

2. The core of the whole theoretical system is the theory of the biosphere and its transition into the noosphere. Vernadsky has seen the biosphere both as a self-organising, homeostating system and as a geological envelope configuring the Earth's surface. The thesis on the evolution of the biosphere had also been clearly stated by Vernadsky, who claimed that the biosphere as a whole possesses its own evolutionary regularities. The evolution of the biosphere is governed by specific biospheric laws such as biogeochemical principles postulated by him. According to the biogeochemical principles, evolution goes in the direction of increasing the level of self-regulation and stability. One of the basic methods of realisation of these „interests" of the biosphere is to increase the intensity and complexity of the biogenic migration of atoms. Evolution that satisfies these 'interests' turns out to be a multi-stage process and, when exhausting one method, it rises to a higher stage. The prediction of Vernadsky that the biosphere must show the properties of a self-regulating system has been corroborated (although not exhaustingly) by the experimental work and mathematical modelling of his successors. Yet Vernadsky did not believe that the evolution of the biosphere has come to the end. He stated that evolution of the biosphere goes in the direction of the progressive self-stabilisation by increasing the biogenic migration of chemical elements. The final stage of this evolution must be the noosphere. The crucial characteristic of the noosphere is that the human reason appears to be the decisive means of the self-regulation of the transformed biosphere. However, Vernadsky failed to convincingly show that the empirical basis of the biosphere theory supports his claims about the inevitable and lawful transition of the biosphere into the noosphere.
3. The second theoretical unity is the theory of the space-time of living matter, which has deep historical roots. In 1848, Pasteur discovered crystalline dissymmetry in the products of wine fermentation, and used this dissymmetrical property as the demarcation line for differentiating living and inert matter. Towards the end of the 19th century, the concept of dissymmetry was adopted by Japp and Curie. Japp proposed that "living matter is constantly performing a certain geometrical feat, which dead matter (inert matter) is incapable of performing" and formulated a general principle that "only asymmetry can beget asymmetry". Curie further developed this principle implying that, if some effects manifest a dissymmetry, then the same dissymmetry must be observable in the causes of those effects, although the inverse is not applicable. From this, Curie developed an idea of a *state of space*

(état de l'espace). Based on the work of Curie, Vernadsky proposed an authorised version of his principle: "*Dissymmetrical effects can be brought about only by a dissymmetrical cause*" and postulated the hereditary character of dissymmetry. This principle separates the spatial properties of living matter from those of the inert environment. The geometrical and physical dissymmetrisation of living matter occurs on five levels: molecular, crystalline (dissymmetry of Pasteur), morphological, temporal and biospheric. Additionally, living matter has been found to exhibit many other peculiar spatial properties such as curvilinearity, dispersiveness, stability and much higher degrees of structural symmetry.

The concept of dissymmetry, being applied to both spatial and temporal properties of living matter, allows for demonstration of the unified nature of space and time. Temporal dissymmetry (irreversibility of time) manifests itself in living matter much more clearly and deeply than in inert matter, thereby implying that there is a crucial difference between two kinds of irreversibility. Time's irreversibility in living natural bodies of the biosphere is nomologically necessary in accordance with the nature of biological space-time, whereas the temporal dissymmetry of inert processes appears to be nomologically contingent according to the laws of physics.

The space-time theory of Vernadsky is required to prove the thesis of the cardinal difference between living and inert matter and, hence, the inexplicability of the biological processes merely by physical-chemical laws. Based on this theory, Vernadsky also made some important corollaries and pre- (retro-) dictions such as the retrodiction about the absence of abiogenesis in the biosphere.

4. In the scientific heritage of Vernadsky, I also distinguish an attempt to create a „scientific theory of science". The concept of scientific thought as a natural planetary phenomenon and a geological force is basic to Vernadsky's philosophy of science and is directly or indirectly connected with all parts of his theoretical system. Scientific thought is seen as the force by means of which the biosphere transforms itself on the latest stage of its evolution. The logic of natural science is a function of the biosphere. The latter is followed by the principle of obligatority and indisputability of correctly made scientific inferences which separate science from philosophy and religion. Based on his philosophy of science, Vernadsky tried to make some predictions, for example, that in the course of time, empirical generalisations will replace theories and hypotheses.

However, as I have shown Vernadsky's philosophy of science is the most disputable part of his theoretical heritage.

5. All three theories compose an unified theoretical system. This is indicated, for example, by the fact that there are concepts which appear in all three parts of the system. One of the illustrative examples is the concept of space-time dissymmetry, which appears in all parts of Vernadsky's theoretical heritage. The space-time theory - the main concept of which is dissymmetry - is required to prove the thesis of the cardinal difference between living and inert matter and, hence, the indeducibility of the biological processes from a separate set of physical-chemical laws. The problem of the cardinal difference between living and inert matter is a very important point, because it is connected with all the important claims of Vernadsky's theoretical system: (i) the first, second and third biogeochemical principles, (ii) the Redi principle, (iii) the concept of the evolution of the biosphere,

(iv) the classification of substances in the biosphere, and (v) the noosphere concept of Vernadsky.

The main objective of Vernadsky's theoretical activity was to support the idea of transition of the biosphere into the noosphere with adequate evidence and arguments. Yet, in our view, he did not succeed in achieving this objective. As I have shown, each part of this theoretical system taken separately and the theoretical system as a whole manifests contradictions and methodological inconsistencies. To sum up: the claims of Vernadsky about the inevitable transition of the biosphere into the noosphere do not follow the empirical base of the biosphere theory. The space-time theory also cannot be used in order to claim the irreversibility of the evolutionary process and of the coming of the noosphere in particular. Vernadsky also did not support well the claim that science performs the leading role in the noosphere.

6. The comparison of the biosphere theory of Vernadsky with the theories of Teilhard de Chardin and James Lovelock shows the boundaries of identity between these theories. Thus, Vernadsky and Teilhard de Chardin used the same scientific data of their time as the empirical basis for their theories. In their theories, the same basic terminology is used: the biosphere, the noosphere, cephalization, living matter, etc. Both theories contain similar methodological principles, such as, the declared principle of phenomenology and the implicit principle of teleology. Nevertheless, Vernadsky and Teilhard created theories with differing views on crucial subjects. Vernadsky rejects abiogenesis; Teilhard accepts abiogenesis; Vernadsky claims that terrestrial intelligence is unthinkable outside of the biosphere; Teilhard brings up the idea of the „splitting of evolution". The concepts of the biosphere and the noosphere are vastly different in both theoretical systems. Vernadsky's and Teilhard's different interpretations of the biosphere and the noosphere concepts can be said to be connected with two divergent properties. Firstly, they had different theoretical premises, in that Teilhard connected the appearance and future development of the human consciousness with the concept of dichotomous matter, while Vernadsky aimed to place humankind into the geological history pointing out the impassable border between living and inert substances. Lastly the differing scientific experience of both theoreticians caused vastly contrasting approaches.

The comparative analysis of Lovelock's Gaia-theory and Vernadsky's theory of the biosphere shows that some crucial theoretical claims, which are fundamental to the Gaia-theory, had already been stated by Vernadsky as early as in the 1920's and 40's. These include: (i) the biogenic character of the atmosphere; (ii) the self-regulating capacity of the biosphere; (iii) the evolution of the biosphere as a whole system including both its biotic and abiotic components. Until the advent of the Gaia-theory theoretical investigation into these topics was continued by the followers of Vernadsky.

Some other important theses of Lovelock's Gaia-theory, however, have no direct analogies in the Vernadskian tradition. These include: (i) the thesis that Gaia has „vital organs and a core"; (ii) the concept of Gaia as a living organism. On the other hand, in contrast to the advocates of Gaia, Vernadsky and Vernadskians paid a lot of attention to defining the biosphere as a biologically manipulated *geological envelope*.

In contrast to Teilhard de Chardin and James Lovelock, Vernadsky never understood the biosphere as the totality of living organisms or as just a domain where life exists or as a living entity. In Vernadsky's theory, the biosphere appears as a „bioinert" self-regulating system and, at the same time, as a geological envelope including both living matter and its inert environment. Bioinert system is defined as a system „which is made by living organisms and inert processes simultaneously and represents the stable dynamic equilibria of both of them".

References

Abram D. (1996), "The Mechanical and the Organic: Epistemological Consequences of the Gaia Hypothesis", in: P. Bunyard (ed.) Gaia in Action, Floris Books, Edinburgh, pp. 234-247.

Aksenov G. (1993) On the Scientific Solitude of Vernadsky. Problems of Philosophy. 6:74-87 [in Russ].

Aksenov G. P. (1994) Vernadsky. Soratnik, Moscow, 542 p. [in Russ].

Aksenov G. P.(1996) On the Cause of Time. Problems of Philosophy 1: 42-51 [in Russ].

Alpatov, V. V. (1957) Left- and Right- handedness in Structure of Organisms of the Plants and Animals. Bulletin of MOIP, depart. biol., vol. (62) 5 [in Russ].

Anderson D.L. (1984) The Earth as a Planet: Paradigms and Paradoxes. Science, 223: 347-354.

Aronov R. & Terentjev V. (1988), Are there Non-Physical Forms of Space and Time? Problems of Philosophy, 1: 71-84 [in Russ].

Bailes K. E. (1990) Science and Russian Culture in an Age of Revolutions: V.I. Vernadsky and His Scientific School, 1863-1945. Indiana University Press, Bloomigton and Indianapolis 238 p.

Baldwin J. M. (ed.) (1901) Dictionary of Philosophy and Psychology. N.Y.

Barrow J., Tipler F. (1986) The Anthropic Cosmoplogical Principle. Claderon Press, Oxford, 706 p.

Barsukov V., Yanshin A. (1988) V.I. Vernadsky - the Great Scholar and Thinker. Proceed. of AN SSSR, 6: 47-56 [in Russ].

Beklemishev V. N. (1994 [written in 1928]) Methodology of Systematics (ed. by G. Lubarsky). KMK Scientific Press Ltd., Moscow, 250 p. [in Russ].

Beklemishev V. N. (1964) On the General Principles of Organisation of Life. Bulletin of MOIP, section Biology, 69 (2): 22-38 [in Russ].

Bergson H. (1969) L' Évolution Créatrice. 142e ed.: Presses Universitaires de France, Paris, 372 p.

Bertalanffy L. von (1973) General System Theory. N. Y., Braziller, 295 p.

Budyko M. I. (1986) Evolution of the Biosphere. Dordrecht: Reidel, 423 p.

Buffon G.-L. (1984) Historie naturelle. (ed. by J. Varloot), Gallimard, Paris, 343p.

Clarke F. W. (1908) Data of Geochemistry. Government Printing Office, Washington, 716 p.

Cohen R. S. (1970) Ernst Mach: Physics, Perception and the Philosophy of Science. In: R. Cohen & R. Seeger (eds.) Ernst Mach: Physicist and Philosopher. Boston Studies in the Philosophy of Science. D. Reidel Publishing Company, Dordrecht, pp. 126-165.

Curie P. (1908), Oeuvres de Pierre Curie. Gauthier-Villar, Paris, 621 p.

Dobzhansky Th. (1970) Genetics of the Evolutionary Process. N. Y., Columbia Univ. Press, 505 p.

Dobzhansky Th. (1990) Letter Exchange between F.G. Dobrzhansky and V.I. Vernadsky. Priroda, 3: 91-96 [in Russ].

Dokuchaev V. V. (1898) Teaching of the Zones of Nature. 2nd ed., 1948, Geografgiz, Moscow [in Russ].

Eddington, A. S. (1928) The Nature of the Physical World. Macmillan, New York, 361p.

Eddington Arthur (1949) Philosophie der Naturwissenschaft. A. Francke AG Verlag, Bern, 287 p.

Eliseev, E.N. (1989), The Development of the Ideas of V.I. Vernadsky and the Contemporary Concepts of Space and Symmetry. In: A.L. Janschin (ed.), Scientific and Social Significance of V.I. Vernadsky's Creativity. Nauka, Moscow, pp. 185-206 [in Russ].

EPW (1995) Enzyklopaedie Philosophic und Wissenschaftstheorie. Blasche S., Mittelstraß J. (Hrsg.), Mannheim-Stuttgart, Bd. 3, 866 p.

Frauenfelder H. (1987), Räumliche und zeitliche Schwankungen in Biomilekülen. In: Raum und Zeit. Vorträge anläßich der Jahresversammlung vom 9. bis 12. April 1980 zu Halle. Deutsche Akademie der Naturforscher, Leopoldina, Halle (Saale), pp. 221-231.

Fuchs-Kittowski K., Krüger P. (1997) The Noosphere Vision of Pierre Teilhard de Chardin and Vladimir I. Vernadsky in the Perspective of Information and of World-Wide Communication. World Futures, 50: 757-784.

Galimov E. M. (1989) The Ideas of Vernadsky and Contemporary Teaching of Fractioning of the Isotopes in Living and Non-Living Nature. In A.L. Janschin (ed.), Scientific and Social Significance of V.I. Vernadsky's Creativity, Nauka, Moscow, pp. 340-344 [in Russ].

Gause G. (1940) Assymmetry of the Protoplasm. Moscow-Leningrad.

Gegamjan G. (1980) About the Biospherology of V.I. Vernadsky. Zhurnal Obshchei Biologii (Journal of General Biology), 41(4):581-594 [in Russ].

Ghilarov A. M. (1994) Vernadsky Vladimir, Darwinism and Gaia - Critical Notes in the Margins of Biosphere. Zhurnal Obshchei Biologii, 55(2): 238-249 [in Russ].

Ghilarov A. M. (1995) Vernadsky's biosphere concept: an historical perspective. The quarterly review of biology. 70(2): 193-203.

Ghilarov A. M. (1998) Lamarck and the Prehistory of Ecology. Internatl. Mikrobiol. 1:161-164.

Ghilarov A. M. (1998) „Pouvoir de la vie": J.-B. Lamarck in the Prehistory of Ecology. Priroda, 4: 21-28 [in Russ].

Glossary of Geology (1982) R. Bates (ed.), Americ. Geol. Inst., Falls Church, X, 751 p.

Goldanskii, V. I. & Semenov, N. N. (1992) Chirality, Origin of Life and Evolution. In: J. & K. Trân Thanh Vân et.al. (eds.), Frontiers of Life, Editions Frontiers, Gif-sur-Yvette Cedex, France, pp. 67-85.

Grinevald J. (1996) Sketch for a History of the Idea of the Biosphere. In: Gaia in Action (ed. by P. Bunyard), Floris Books, Edinburgh, pp. 34-53.

Gruenbaum A. (1974) Philosophical Problems of Space and Time. Reidel, Dordreht, 884p.

Horwich, Paul (1987) Asymmetries in time: problems in the philosophy of science. MIT Pr., Cambridge, Mass., 218 p.

Hutchinson G. E. The Biosphere. Scientific American, 1970, 223 (3): 45-53.

Jahn I. (ed.) (1982) Geschichte der Biologie: Theorien, Methoden, Institutionen, Kurzbiographien. Gustav Fischer Verlag, Jena, 859 p.

Jahn I. (ed.) (1998) Geschichte der Biologie: Theorien, Methoden, Institutionen, Kurzbiographien. 3rd ed. Gustav Fisher Verlag, Jena.

Jantsch E. (1981) The Evolutionary Vision: Toward an Unifying Paradigm of Physical, Biological, and Sociocultural Evolution. Westview Press, Boulder Colo, 222 p.

Japp, F.R. (1898) Stereochemestry and Vitalism. Nature, 1506: 452-460.

Kamshilov M. (1979) Evolution of the Biosphere. Nauka, Moscow, 256 p. [in Russ].

Kattmann U. (1991) Bioplanet Erde: Neue Ansichten über das Leben. Unt. Biol. 15(162): 51-53.

KEL (1978) Kleine Enzyklopaedie Leben. Geissler E. (ed.), Bibliogr. Inst., Leipzig, 896 p.

Kingsland Sharon (1995) Modelling Nature: Episodes in the History of Population Ecology. The University of Chicago Press, Chicago and London, 306 p.

Kolchinskij E. (1990) Evolution of the Biosphere. Nauka, Leningrad, 236 p. [in Russ].

Kolchinskij E. & Kozulina A. (1998) The Burden Of Choice: Why Did V.I. Vernadsky Return to the Soviet Russia? Voprosy istorii estestvoznanija i tekhniki, 3:3-25 [in Russ].

Krasnogorskaja N. V. (ed.) (1992) Contemporary Problems of Researching and Preserving of the Biosphere. Gidrometeoizdat, Sankt-Petersburg, in III vol., vol. 1, 285 p. [in Russ].

Krout I. V. (1983), "Vladimir Ivanovich Vernadsky", in: Freeman, T. W. (ed.) Geographers: Bibliographical Studies, Vol. 7, Mansell Publ., London.

Krumbein W. E. (1978) Geomicrobiologische Prozesse bei der Anreicherung nutzbarer Minerale und sedimentärer Lagerstätten. In: Erdöl und Kohle, Erdgas, Petrochemie, 31(3): 147-151.

Krumbein W. E. (ed.) (1983) Microbial Geochemistry. Blackwell, London, 330 pp.

Krumbein W. E. (1990) Der Atem Cäsars. In: Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg, 69: 267-301.

Krumbein W. E., Schellnhuber H.-J. (1991) Geophysiology of Carbonates as a Function of Bioplanets. In: S. Kempe, W. Michaelis, V. Ittekott & A. Spitzy (Eds.), Perspectives in Biogeochemistry. Springer, Berlin, pp. 5-22.

Krumbein W. E., Schellnhuber H.-J. (1992) Geophysiology and Mineral Deposits - a Model for a Biological Driving Force of Global Changes Through Earth History. Terra Nova, 4: 351-362.

Krumbein, W. & Lapo A. (1996) Vernadsky's Biosphere as a Basis of Geophysiology. In: P. Bunyard (ed.) Gaia in Action, Floris Books, Edinburgh, pp. 115-135.

Krumbein W. E. (1996) Geophysiology and Parahistology of the Interactions of Organisms with the Environment. Marine Ecology, 7(1-3):1-21.

Kutyrev V. (1990) Utopia and Reality in the Teaching of the Noosphere. Priroda, 11: 3-10 [in Russ].

Lamarck J.-B. (1802) Hydrogéologie. Agasse, Maillard, Paris, an X.

Lapo A. V., Smyslov A.A. (1986) V.I. Vernadsky - the Founder of Biogeochemistry. In: V. I. Vernadsky and the Modernity, Nauka, Moscow, pp. 123-129.

Lapo A. V. (1987) Traces of Bygone Biospheres. Moscow, „Znanije", 207 p. [in Russ].

Lapo A.V. (1987[1]) Traces of Bygone Biospheres. Moscow, „Mir Publishers", 306 p.

Lapo A.V. & Smyslov A.A. (1989) Biogeochemistry: The Foundations Laid by V.I. Vernadsky. In: Scientific and Social Significance of Vernadsky's Creativity, ed. by acad. A. L. Yanschin, Nauka, Moscow, pp. 54-61 [in Russ].

Le Roy E. (1927) L'exigence idéaliste et le Fait d'Evolution. Alcan, Paris.

Le Roy E. (1928) Les Origines humaines et l'évolution de l'intelligence, Boivin, Paris.

Liebscher H. (1997) Theorie. In: Hörz H. et al. (Hrsg.), Philosophie und Naturwissenschaften. Woerterbuch", PAHL-RUGENSTEIN, Bonn, pp. 890-891.

Levit G., Krumbein W., Gorbushina A. (1999) Geophysiology of cyanobacterial biofilms and the dyssymmetry principle. Marine Cyanobacteria, Charpy L. & Larkum A.W.D. (eds.), Bulletin de l'Institut Océanographique, Monaco, Special Issue, 19:175-196.

Levit G., Krumbein W. (1999) The Biosphere Theory of V.I. Vernadsky and the Gaia Theory of J. Lovelock: a Comparative Analysis of the Two Theories and Two Traditions. Zhurnal Obshchei Biologii (Journal of General Biology), 61(2): 133-144.

Lorenz, Konrad (1941) Kant's Lehre vom apriorischen im Lichte gegenwaertiger Biologie. Blaetter fuer Deutsche Philosiphie, 15: 94 - 125.

Löther R. (1998) Evolution der Biosphäre und Ethik. In: Engels, Junker & Weingarten (eds) "Ethik der Biowissenschaften", Berlin, pp. 61-68.

Lotka A. (1925) Elements of Physical Biology. Baltimore, 460 p.

Lovelock J. (1972) Gaia as Seen through the Atmosphere. Atmos. Envir. 6:579f.

Lovelock J. and Margulis L. (1974) Atmospheric Homeostasis by and for the Biosphere: the Gaia Hypothesis. Tellus, 26: 2-10.

Lovelock J. (1989) Gaia: A New Look at Life on Earth. Oxford Univ. Press, 157p.

Lovelock J. (1989[1]) The Ages of Gaia: A Biography of our Living Earth, Oxford Univ. Press, 252 p.

Lovelock, J. (1986) The Biosphere. New Scientist, 1517: 51.

Lovelock, J. (1996) The Gaia Hypothesis. In: P. Bunyard (ed.), Gaia in Action, Floris Books, Edinburgh, pp. 15-16.

Mach Ernst (1987) Populär-wissenschaftliche Vorlesungen. Wien, Boehlau Verlag.

Margulis L. (1988) Jim Lovelock's Gaia. In: Gaia, the Thesis, the Mechanisms and the Implications, P. Bunyard, E. Goldsmith (ed.), Cornwall, pp. 50-62.

Margulis, L. & Sagan, D, (1995) What is Life? A Peter N. Nevraumont Book, N.Y., 207p.

Margulis Lynn (1996) James Lovelock's Gaia. In: Gaia in Action, (ed. P. Bunyard), Floris Books, Edinburgh, pp. 54-65.

Mayr E. (1982) The Growth of the Biological Thought. The Belknap Press, Cambridge-London, 974 p.

Mayr E. (1998) Das ist Biologie: die Wissenschaft des Lebens. Spektrum, Akad. Verlag, Heidelberg-Berlin, 439 p.

McMenamin M. (1998) Comments to „The Biosphere" of Vernadsky. In: Vernadsky V.I., The Biosphere, A Peter A. Nevraumont Book, N.Y., 192 p.

Mehlberg, H. (1961) Physical Laws and Time's Arrow. In: H. Feigl and G. Maxwell (eds.), Current Issues in the Philosophy of Science. Holt, Rinehart, and Winston, New York.

Mikulinskij S. (1989) About the Essence and Origin of the Noosphere Teaching of V.I. Vernadsky. In: Scientific and Social Significance of Vernadsky's Creativity, ed. by acad. A. L. Yanschin, Nauka, Moscow, pp. 98-107 [in Russ].

Mirzoyan E. (1994) Theory of Living Matter of V.I. Vernadsky. Journ. of General Biology, 55 (1): 13-29 [in Russ].

Mochalov I.I. (1971) Scientific and Philosophical Foundations of V.I. Vernadsky's Worldview. Autorreferat, MGPI, Moscow, 33 p. [in Russ].

Mochalov I. I. (1982) Vladimir Ivanovich Vernadsky. Nauka, Moscow, 448 p. [in Russ].

Moiseev N., Alexandrov V., Tarko A. (1985) The Man and the Biosphere. An Attempt at System Analysis and Experiments with Models, Moscow: Nauka, 271 p. [in Russ].

Monod J. (1971) Zufall undo Notwendigkeit: philosophische Fragen der moderne Biologie. Piper, München, XV, 237 p.

Pasteur L. (1922) Oeuvres de Pasteur. Tome premier, Masson et Cie, Éditeurs, Paris.

Popper Karl (1968) Is there an epistemological problem of perception? In: Lakatos Imre, Musgrave Alan (eds.), Problems in the philosophy of science, North-Holland Publishing Company, Amsterdam, 1968 pp. 40-64.

Sahtouris Elisabet (1995) Earthdance: Living Systems in Evolution. http://www.ratical.com/LifeWeb/Erthdnce/chapter7.html.

Sahtouris Elisabet (1996) The Gaia Controversy: a Case for the Earth as an Evolving Organism. In P. Bunyard (ed.), Gaia in Action, Floris Books, Edinburgh, pp. 324-338.

Samoilov (1929) The Biolits. Leningrad, 140 p. [in Russ].

Savitt Steven F. (1996) The Direction of Time. Brit. J. Phil. Sci., 47: 347-370.

Schlick M. (1930), Die Wende der Philosophie. Erkenntnis, N1.

Schellnhuber H.-J., Wenzel V. (eds.) Earth System Analysis. Integrating Science for Sustainability. Berlin; Heidelberg: Springer, 530 p.

Shinkaruk V. (1988) To the Question about the Philosophical Views of V.I. Vernadsky. Problems of Philosophy, 7: 128-133.

Schrödinger, E. (1992) What is life? Cambridge University Press, Cambridge, 184p.

Serafin R. (1987) Vernadsky's Biosphere, Teilhard's Noosphere, and Lovelock's Gaia: Perspectives of Human Intervention on Global Biogeochemical Cycles. Austria, International Institute for Applied Systems Analysis, Laxenburg.

Serafin R. (1988) Noosphere, Gaia, and the Science of the Biosphere. Environmental Ethics, 10: 121-137.

Serafin R. (1993) Round Table Discussions, in Vernadsky Vladimir Biography. Selected works. Reminiscences of contemporaries. Opinions of descendants. Moscow, „Sovremennik" [in Russ].

Sitnik K., Apanovich E., Stoiko S. (1988) V.I. Vernadsky. Life and Activity in the Ukraine. Kiev, Naukova Dumka, 366 p. [in Russ].

Stempell W. (1926) Zoologie im Grundriss. Berlin, 1926.

Svetlov P. G. (1994) In Memory of Vladimir Nikolaevich Beklemishev (1890 -1962). In: V.N. Beklemishev, Methodology of Systematics, KMK Scientific Press, Moscow, pp. 6-16 [in Russ].

Suess E. (1875) Die Entstehung der Alpen. Braunmuller, Wien, 168 p.

Suess E. (1909) Das Antlitz der Erde. Wien, Leipzig, Bd. 3, 789 p.

Teilhard de Chardin P. (1955) Le Phénomène humain. Éditions du Seuil, Paris, 348p.

Teilhard de Chardin P.(1959), L'avenir de l'homme. Seuil, 405 p.

Teilhard de Chardin P. (1961) The Phenomenon of Man. 1961, Harper & Row, N.Y. and Evanston, 318 p.

Thompson, D'Arcy (1961) On Growth and Form. J.T. Bonner (ed.), Cambridge University Press, Cambridge, 346 p.

Timofejeff-Ressovsky N. V., Tjurjukanov A.N. (1966) On the Elementary Biochorological Subdivisions of the Biosphere. Bulletin MOIP, Depart. Biology, LXXI (1): 123-132 [in Russ].

Urmantsev, J. A. (1974) Symmetry of Nature and Nature of Symmetry. Mysl, Moscow [in Russ.].

Vassoyevich N. B., Ivanov A. N. (1977) On the History of the Concept of the Biosphere. In: The Methodology and History of Geological Sciences, Nauka, Moscow, pp. 57-94 [in Russ].

Vernadsky V. I. (1923) Living Matter in the Chemistry of the Sea. Petrograd, Scientific Chemical-Technical Publishing House, 36 p. [in Russ].

Vernadsky W. I. (1923[1]) A Plea for the Establishment of a Biogeochemical Laboratory. The Marine Biol. Stat. of Port Erin. Ann. Rep., 37: 38-43.

Vernadsky V. I. (1924) La Géochemie. Alcan, Paris, 404 p.

Vernadsky V. I. (1926) Isotopes and Living Matter. Reports of Acad. of Sc. of the USSR, series A, Dec., pp. 215-218 [in Russ].

Vernadsky V. I. (1928) The Evolution of Species and Living Matter. Priroda, 3: 227-250 [in Russ].

Vernadsky V. I. (1928[1]) Ueber die geochemische Energie des Lebens in der Biosphere. Zbl. Mineral., Geol., Paläontol., Abt. B, 11: 583-594.

Vernadsky V. I. (1929) La Biosphere. Alcan, Paris, 232 p.

Vernadsky V. I. (1930) Geochemie in Ausgewählten Kapiteln. Autorisierte Überactung aus dem Russischen von Dr. E. Kordes. Akadem. Verlagsgesellschaft, 370 p.

Vernadsky V. I. (1931) The Study of Phenomena of Life and Modern Physics. Bulletin of the Academy of Science of the USSR, series 7, OMEN, 3: 403-437.

Vernadsky V. I. (1932) Die Radioactivität und die neuen Probleme der Geologie. Z. Elektrochem., 38 (8-a):519-527.

Vernadsky (1932[1]) Problem of Time in the Modern Science. Bulletin of the Academy of Science of the USSR, series 7, OMEN, 4: 511-541 [in Russ].

Vernadsky V. I. (1933) In Connection with the Critical Comments of acad. Deborin A.M. Bulletin of the Academy of Science of the USSR, series 7, N 3, pp. 395-407 [in Russ].

Vernadsky V. I. (1933[1]) History of the Minerals of the Earth's Crust, vol. 2: History of Natural Waters. Part 1. Iss. 1. Goshimtekhizdat, 202 p. [in Russ].

Vernadsky V. I. (1934) History of the Minerals of the Earth's Crust, vol. 2: History of Natural Waters. Part 1. Iss. 2, ONTI, Khimteoret, Leningrad, pp. 201-402 [in Russ].

Vernadsky V. I. (1934) Le Problème du Temps dans la Science Contemporaine. Revue Génerale des Sciences Pures et Appliquees, 45(20):550-558.

Vernadsky V. I. (1935) Le Problème du Temps dans la Science Contemporaine. Revue Génerale des Sciences Pures et Appliquees, 46 (7):208-213; 47(10):308-312.

Vernadsky V. I. (1936) History of the Minerals of the Earth's Crust, vol. 2: History of Natural Waters. Part I. Iss. 3, Khimteoret, Leningrad, pp. 403-562 [in Russ].

Vernadsky V. I. (1939) On the Significance of Radiology for the Contemporary Geology. In: Proceedings of the 17th International Geological Congress. USSR. 1937, vol.I, GONTI, Moscow, pp. 215-239 [in Russ].

Vernadsky V. I. (1931) Probelms of Biogeochemistry. II. About the Essential Material and Energetic Difference Between Living and Non-Living Natural Bodies of the Biosphere. AN SSSR, Moscow-Leningrad, 34 p.

Vernadsky V. I. (1931[1]) On the Conditions of the Appearance of Life on Earth. Proceed. of AN SSSR, series 7, OMEN, 5: 633-653.

Vernadsky V. I. (1940) Biogeochemical Essays 1922-1932. Moscow-Leningrad, 250p.

Vernadsky V. I. (1944), A Few Words About the Noosphere. The Successes of Biology. Uspechi Biologii, 18(2):113-20 [in Russ].

Vernadsky, V. I. (1965) The Chemical Structure of the Biosphere of the Earth and of its Environment. Nauka, Moscow, 374 p. [in Russ.].

Vernadsky V. I. (1978) Living Matter. Moscow, Nauka, 358 p. [in Russ].

Vernadsky V. I. (1980) Problems of Biogeochemistry. III, BIOGEL, vol. 16 [in Russ].

Vernadsky V. I. (1988) Works on the General History of Science. Moscow, Nauka, 467 p. [in Russ].

Vernadsky V. I. (1988[1]) Philosophical Thoughts of Naturalist. Moscow, Nauka, 520 p. [in Russ].

Vernadsky V. I. (1991) Scientific Thought as a Planetary Phenomenon. Moscow, Nauka, 271 p. [in Russ].

Vernadsky V.I. (1993) Diary of 1940. Druzhba Narodov, 9:173-194.

Vernadsky, V. I. (1993[1]) The Study of Phenomena of Life and Modern Physics. In: G. Aksenov (ed.), Vernadsky Vladimir. Biography. Selected works. Reminiscences of contemporaries. Opinions of descendants. Sovremennik, Moscow, pp. 355-394 [in Russ.].

Vernadsky V. I. (1994) Living Matter and the Biosphere. Moscow, Nauka, 671 p. [in Russ].

Vernadsky V. I. (1994[1]) Works on Geochemistry. Nauka, Moscow, 495 p. [in Russ].

Vernadsky V. I. (1994[2]) Diaries 1917-1921. Kiev, Naukova Dumka, 280 p. [in Russ].

Vernadsky V. I. (1997) Scientific Thought as a Planetary Phenomenon. Nongovernmental Ecological V.I. Vernadsky Foundation, Moscow, 265 p.

Vernadskij V. I. (1997[1]) Der Mensch in der Biosphaere: zur Naturgeschichte der Vernunft. Lang, Frankfurt am Main, 249 p.

Vernadsky V. I. (1998) The Biosphere. A Peter A. Nevraumont Book, N.Y., 192p.

Vinogradov A.P. (1935) The Chemical Elemental Composition of Sea Organisms. In: The Works of the Biogeochemical Laboratory, 3: 63-278 [in Russ].

Vinogradov A. P. (1937) The Chemical Elemental Composition of Sea Organisms. In: The Works of the Biogeochemical Laboratory. 4: 5-225 [in Russ].

Vinogradov A. P. (1944) The Chemical Elemental Composition of Sea Organisms. In: The Works of the Biogeochemical Laboratory, 6: 4-273 [in Russ].

Watson A. (1988), The Gaia Hypothesis - Mechanisms and Tests, in: „Gaia, the Thesis, the Mechanisms and the Implications", P. Bunyard, E. Goldsmith (ed.), Cornwall, pp. 66-75.

Weyl H. (1966) Philosophie der Mathematik und Naturwissenschaft. R. Oldenbourg, München - Wien, 406 p.

Yanshina, F. T. (1994), Origin of Life in the Works of Vernadsky. In: A.L. Yanshin (ed.), V.I. Vernadsky. Living Matter and the Biosphere. Nauka, Moscow, pp. 647-656 [in Russ].
Yanshina, F. T. (1996) The Evolution of V. I. Vernadsky's Views on the Biosphere and the Development of the Noosphere Doctrine. Nauka, Moscow [in Russ.].
Zavarzin G. A. (1997), The Rise of the Biosphere, Microbiology, (66)6: 603-611.