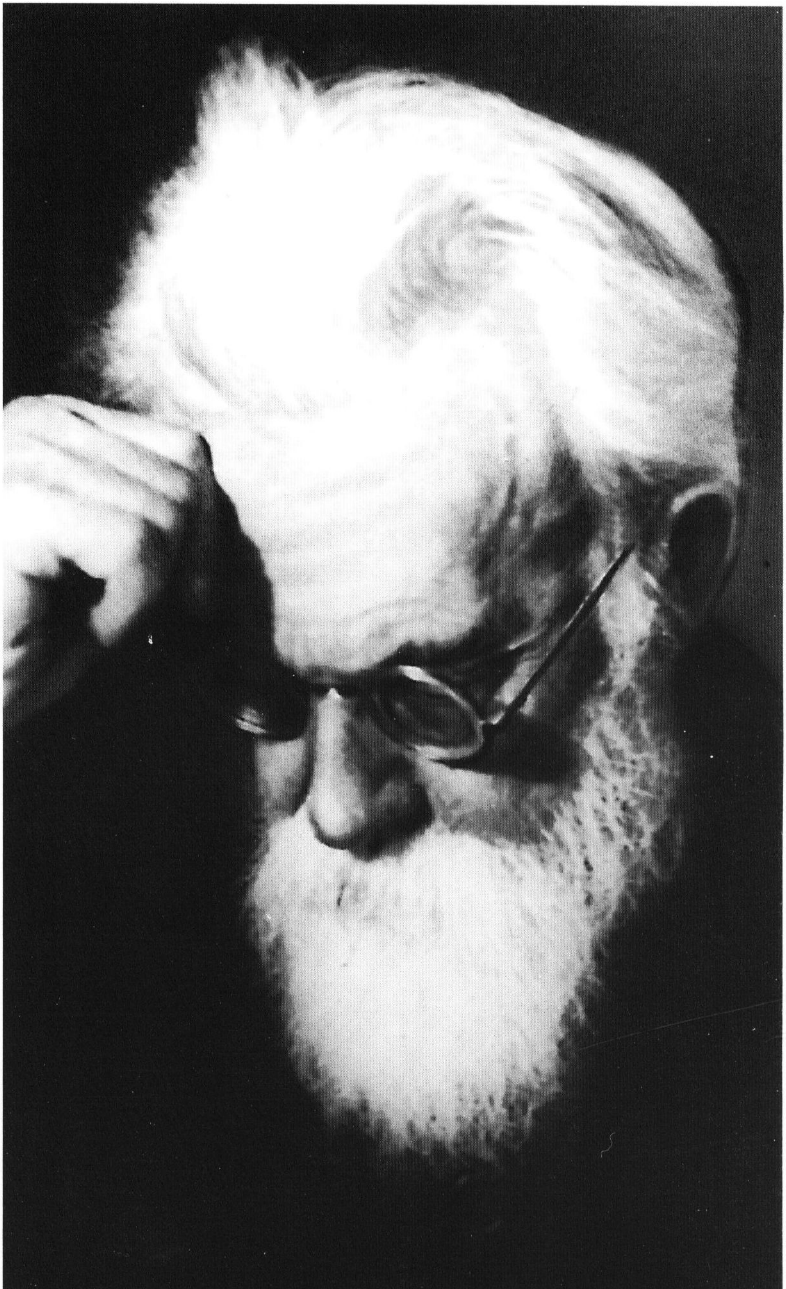
V. I. VERNADSKY

SCIENTIFIC THOUGHT AS A PLANETARY PHENOMENON



V. I. Vernadsky

SCIENTIFIC THOUGHT

AS A PLANETARY PHENOMENON

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The book was prepared with participation of the Commission on Studying Scientific Heritage of the Academician V.I .Vernadsky, Russian Academy of Sciences.

Preface and commentary :
Chairman of the Commission on Studying Scientific Heritage of the Academician V. I. Vernadsky, RAN, Academician *A.L. Yanshin.* Leading Scientist of the V.I.Vernadsky Institute of Geochemistry and Analytical Chemistry *F. T. Yanshina.*

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This monograph presents a sort of a summary of creative searches of our great compatriot V.I.Vernadsky, a summary of his deep thoughts on the fortunes of the scientific cognition, on the relations of science and philosophy, on the future of the mankind. Following the ways and the stages of the development of scientific thought at different historical epochs, the author emphasizes the inequality of this development. The scientist dramatizes the leading constructive role of the science and socially organized human labor in the present and future of our planet.

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PREFACE

The name of the Academician Vladimir Ivanovich Vernadsky has been always deeply honored in Russia and Ukraine, and recently has become widely known, especially in connection with topicality of his doctrine of the Earth's biosphere and its inevitable evolutionary transformation into the sphere of the human reason (the noosphere). Every intelligent man in Russia has read either the works by Vernadsky or at least some of the numerous articles about him and his heritage scattered over newspapers and magazines.

In Moscow, after V. I. Vernadsky are named the academic Institute of geochemistry and analytical chemistry, State museum of geology, an avenue, an underground station; in St. Petersburg - the Biosphere museum situated in the building of the secondary school where V. Vernadsky studied; in Kiev - an avenue and the library of the Sciences Academy of the Ukraine (a monument of the scientist is raised near the library). The Russian Academy of Sciences awards the golden medal and prizes in honor of Vernadsky. To the Presidium of this Academy, a Commission for studies in the scientific heritage of Vernadsky is attached.

In four universities of Russia and Ukraine, the best students are awarded the advanced scholarships and prizes of Vernadsky. The Vernadsky non-governmental ecological foundation has been lately organized to disseminate Vernadsky's ideas. In particular, this foundation has sponsored the publication of this book. The research ship *Academician Vernadsky* is ploughing the southern seas, and the steamship *The geologist Vernadsky* sails on the river Kama. In Crimea, near Simferopol, there exists a settlement Vernadovka, and at the Kazan railway, the station of the same name.

In honour of V. I. Vernadsky, the geographers have named a peak in the basin of the Podkamennaya Tunguska river, a volcano on Paramushir Island, a peninsula and glacial mountains in the Eastern Antarctica. The mining engineers know the Vernadsky mine in the Transbaikalian area, the astronomers—the Vernadsky crater at the back side of the Moon, the mineralogists—a new sulphate mineral "vernadite"; the botanists named after Vernadsky a new species of diatoms, and the oceanologists—a submarine volcano and a recently discovered latitudinal fracture zone of the Earth's crust at the floor of the Atlantic Ocean.

Who was this man whose name is given to the most diverse natural objects as well as to institutes, steamships, streets, and populated areas; in whose honor the golden medals, prizes, and scholarships are awarded?

V. I. Vernadsky was born in St. Petersburg on March 12, 1863. He graduated from the Petersburg University in 1885 and after that during two years enlarged his education in the Universities of the Western Europe. Since 1890 to 1911, he taught mineralogy and crystallography in the University of Moscow. In 1897, he maintained his thesis for a Doctor's degree. In 1905, he was elected a junior scientific assistant, in 1912—a full member of the Russian Academy of Sciences. He worked in its departments for 33 years and died in Moscow on January 6, 1945.

From the chronology of his life one may see that V.I.Vernadsky was a Russian scientist. Still in Ukraine, he is considered to be a Ukrainian scientist and it is not devoid of foundation. His ancestors were the Dnieper Cossacks. His father, before his move to Petersburg, taught political economy in the Kiev University. In 1918, V. I. Vernadsky himself organized the Ukrainian Academy of Sciences and became its first president. Vernadsky's country cottage was in Shishaki, near Poltava. Now at this place the Vernadsky's museum exists.

V. I. Vernadsky never was an armchair scientist. He voyaged extensively throughout the territory of the then Russia, later the Soviet Union and over the countries of Central and Western Europe as well as through Italy and Scandinavia. In 1913, he visited Canada and the United States; everywhere he worked in museums and libraries. He knew well European languages and kept friendly relations or correspondence with all eminent scientists of his time.

V. I. Vernadsky was very punctual, concentrated, and unusually fertile in his work. His numerous books and papers left a deep trace in many areas of natural science. According to the decision of the Presidium of the Academy of Sciences, Vernadsky's complete works began to be published under the title

The Library of the Works of Academician V. I. Vernadsky. This collection is to include the translations into Russian of all Vernadsky's paper published outside Russia as well as all his manuscripts which still remain unpublished and are kept in various archives. In 1992, the first volume of this edition, *Works in Biogeochemistry and Geochemistry of Soils,* was published. In 1994, two more volumes were published: *Living Substance and Biosphere* and *Works on Geochemistry.* In 1995, the *Publicistic Papers* of V. I. Vernadsky were published. *Works on Radiogeology* and *Works on Scientists and their Creativity* are in the process of being published. In 1992, a complete bibliography of V.I.Vernadsky's works was published.

The research and organizational activity of V. I. Vernadsky was very highly estimated by his contemporaries. After his death, V. L. Komarov, President of the Academy of Sciences, wrote: "V.I.Vernadsky's scientific ideas covered many geological, physical-chemical, and biological disciplines. A modern geologist, chemist, geophysicist, biologist finds in his works remarkable fruitful ideas. He writes about contemporary theory of atomic nuclei, on the distribution of radium, on the Cretaceous deposits, on the results of the life activity of the organisms, on the chemical composition of the living organisms. Everywhere he gives original solutions, and everywhere, his thoughts remain a fruitful source for further progress of science"[1].

A. E. Fersman, the nearest pupil of V. I. Vernadsky and his successor in the area of the development of geochemistry, who only outlived his teacher by several months, had time to write about V. I. Vernadsky: "His general ideas will be studied and elaborated during centuries and one will discover new pages in his works which will serve as the source for new searches. Many scientists will learn his creative thought which is acute, stubborn and articulated, always genial, but sometimes poorly understood. As for young generations, he always will be a teacher in science and a striking example of a fruitfully lived life".[2]

[1] V. A. Komarov. *In memorium V I. Vernadsky.* Pravda, 1948, January 8; Izvestiia, 1948, January 9.

[2] A. E. Fersman. *The Life of the Academician Vladimir Ivanovich Vernadsky (1863-1945).* Papers of the All-Russian mineralogical society. Series. 1946. Pt. 75. no. 1. pp. 5-24.

Analogous were the comments of other scientists who had known scientific works of V. I. Vernadsky and paid high tribute to them.

In the beginning of his scientific activities, V. I. Vernadsky worked as a soil scientists. In the 1880s, he participated in the expeditions which had been organized by his loved teacher Dokuchaev, the founder of the modern soil science. These expeditions explored the soils in the various regions of Russia. Studying the mineral composition of different soils, Vernadsky became deeply interested in mineralogy and crystallography. These sciences for long years became the main areas of his scientific inferences and of his activities as a professor. His thesis for a Doctor's degree dealt with a crystallographic topic: *On the sliding phenomena in the sillimanite crystals.* But his contributions to mineralogy are still more important. Among these contributions, one must note the genetic approach. He emphasized the connection between the crystallization form, hardness, color, and other physical properties of minerals and their chemical composition, as well as the conditions of their genesis. He investigated in detail many silicate minerals and published a monograph *An Essay in Descriptive Mineralogy* in many volumes.

Water was considered by V. I. Vernadsky to be a liquid mineral. He collected many precise analyses of natural waters and came to a conclusion that their primary chemical composition has almost everywhere been changed by human impact. With reference to this fact, V. I. Vernadsky advanced a complex chemical classification of all the surface and underground waters of our planet.

Studying the chemical composition of minerals, V. I. Vernadsky became interested in the distribution of individual chemical elements in the Earth's crust, hydrosphere, and atmosphere, i.e. in the knowledge field, which was as early as in 1842 named *geochemistry* by the Swiss scientist Chistian Schonbein. This very appropriate term remained neglected during long years, and only in the early 20th century the science corresponding to this term was created in the works by F. W. Clarke, V. M. Goldschmidt, and V. I. Vernadsky.

V. I. Vernadsky published many papers on geochemistry of various elements, and his main work *La Geochimie* was published in French in 1924 in Paris where he was invited by the head of the University of Paris, Paul Appele, to read lectures in this (new at that time) scientific discipline. In 1927, the first Russian edition of this book was published, and since then many times republished. In 1930, the book was published in Leipzig in a German translation, and in 1933, in Tokyo, in a Japanese translation. In this book, the geochemistry of carbon, as a constant component of all organic compounds, is described in the utmost detail. The carbon cycles in the living and nonliving nature are described. The problem of the organic origin of oil and other hydrocarbon compounds of the Earth's crust is thoroughly considered. The final chapter of the book deals with the geochemistry of radioactive compounds.

V. I. Vernadsky was one of the first scientists who predicted the possibility of controling the rate of radioactive decay and using radioactive elements as energetic raw materials. As early as in 1910, he hold a lecture *Topical problem in the study of radium* at the general meeting of the Academy of Sciences. In 1911, the lecture was published. The lecture contained a comprehensive program of the geological, chemical, and technological investigations directed to the search of the uranium ores and to their study as possible raw materials for the production of power. At the same time, Vernadsky organized a special commission which began searching uranium ores in the various regions of Russia. In 1916, the first uranium deposit was discovered in the Middle Asia, and in 1918, its ores gave the first milligrams of radium in Russia.

In the early 1922, V. I. Vernadsky managed to organize in Petersburg the Radium Institute which is actively working up to our time. To 1938, he remained its director. In the day of the opening of the Institute, Vernadsky held a speech which at the same time was published. He spoke about the inevitability of the soon mastering of the energy of the atomic decay and warned about the eventual danger of this discovery. He said and wrote: "Soon man will have atomic power at his hands. This is a power source which will give him a possibility to build his life just as he wishes. Will he be able to use this force for good purposes and not for self- destruction? A scientist must feel responsibility for the results of his studies!"

This was the first time when a warning about the threat of the atomic war sounded.

Simultaneously with geochemistry and radiogeology, V. I. Vernadsky studied many problems in the history of scientific knowledge. He has written basic works on the development of natural sciences in the 18th century, on the various periods in the activities of the Russian Academy of sciences, on the works by the brilliant Russian scientist M. V. Lomonosov, as well as many papers on the research made by individual scientists. In particular, he published interesting large articles on the natural-scientific heritage of I. Kant and I. Goethe. In 1921, he organized the Commission on the history of scientific knowledge, which some years later had been enlarged and transformed into the Institute of the history of natural science and technology, which proceeds working successfully even today. V. I. Vernadsky was the director of this Institute to 1932.

It should be noted that as early as in 1921 he began studying meteorites and cosmic dust. He published a series of papers in this area. In 1935, he organized the Committee on meteorites of the Academy of sciences. He guided the works of this Committee up to the end of his life.

But of the greatest importance for our days is V. I. Vernadsky's doctrine on the biosphere of the Earth and on the inevitability of the evolutionary transformation of the biosphere into the reign of the human reason—the noosphere.

As early as in his student years, he manifested a profound interest to the living nature. It is evidenced by his most early publications of the 1880s.

Later, he studied the distribution and migration of various chemical elements in the Earth's crust as well as in the other Earth's spheres (hydrosphere, atmosphere). During these studies, he naturally became interested in the content of these elements in various tissues of animals and plants.

In 1917-1921, the years of Russian revolution and civil war, V. I. Vernadsky worked at the territory of contemporary Ukraine, in Poltava and Kiev, where he organized the Ukrainian Academy of sciences, and in Simferopol, where he was elected the head of the University. All these years, he managed to find time for studying into complete chemical composition of various organisms. Already these first studies showed that almost all known chemical elements may be found in some or other organs of the animals and plants. To that, sometimes even the minor quantities of an element have a certain physiological importance. Some organisms (especially among insects, unicellular organisms, and bacteria) turned out to be the concentrators of some chemical elements. For example, it had been discovered that in the soils and natural waters of the Transbaikalian region the calcium content is very low, while the content of strontium is very high; this leads to the so called *Urovo disease*—the abnormal forms of the growing skeleton. The lack of copper in the peat soils of Belorussia causes the lying down of the cereals; the lack of boron in the soils causes a slow putrefaction in the roots of the vegetables; and a tiny quantity of molybdenum increases the harvest of wheat and rye. Later on, all these biogeochemical peculiarities came into use in agrochemistry.

Immediately after his return to Petersburg in 1921, V. I. Vernadsky traveled to a biological station near the Barents Sea for the study of the chemical composition of the various marine organisms. Having returned from there, he published an article *Living substance in the chemistry of the sea.* Here, he used, for the first time, the term *biogeochemistry* to designate a new research direction which he developed. After his opinion, this science is not to study the complete chemical composition of various tissues of the animals and plants, but also of all chemical reactions between the living substance of the organisms and the inert substance of the environment which surrounds them.

From May, 1922 to May, 1926, as it was said before, V. I. Vernadsky worked in Paris. After his return to Petersburg in 1927, he organized a special biogeochemical laboratory of the Academy of Sciences, which had published a series of collections *Problems of Biogeochemistry.* V. I. Vernadsky was the editor of these collections. After the end of the World War II, this laboratory became a base for the then newly organized, now widely known V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry.

In his studies of the living substance, V. I. Vernadsky approached an analysis of the structure of the envelope of the Earth within which this substance exists. As early as in 1875, an Austrian geologist Edward Suess called this envelope *biosphere,* i.e. the sphere of life. However, neither Suess nor other scientists analyzed the content of this term in detail.

As to V. I. Vernadsky, he worked out an overwhelming doctrine concerning the biosphere of the Earth. He defined the boundaries of the biosphere by having shown that the biosphere includes all the hydrosphere, troposphere to a height of about 30 km, and the upper part of the Earth's crust down to a depth of two or three kilometers, for living bacteria still may be found at this depth in the underground waters and in the oil. He estimated the total mass of the living substance in the biosphere and described the regularities of its spatial distribution. In doing this, he identified the films of the concentrated living substance which correspond to the soil (on dry land) or to a few upper meters of the water (in the oceans).

V. I. Vernadsky calculated the amount of cosmic energy received by the biosphere by means of capturing (by the chlorophyll of the green plants) of solar radiation. He calculated, which portion of this energy is spent on movement, reproduction, and other functions of the living substance of the biosphere; which portion is spent by the organisms on the destruction of the rocks and on the creation of the new minerals in the biosphere; and which is buried (together with the organic matter) in the sedimentary rocks and so transfers the solar energy into the Earth's crust, creating in the end the deposits of coal, oil, and combustible gas.

V. I. Vernadsky studied the velocities at which various species of the organisms diffuse in the biosphere. He worked out a mathematical technique for defining their impact on their environment. He calculated the cycles of chemical elements passing through the living substance. In short, he made the main features of the biosphere structure and life clear for everybody.

V. I. Vernadsky's biosphere is not a static *life envelope,* but an open system having existed since the very beginning of the Earth's history. The contemporary life and its activities are the product of a long and complex evolution of the living substance. To that, this historical development is continuous, directed, ireversible and irregular.

V. I. Vernadsky's doctrine on the biosphere is set forth by him in numerous papers published in the 1920s and in the early 1930s not only in Russian scientific journals, but also in French (33 papers), English, German, Belgian, and Czech ones; also in three monographs from which only the first and the earliest one is widely known. It has been published in Russian in 1926 under the title *Biosphere*, in French (in author's translation) in 1929, in English (an abridged edition) in 1986. Two other monographs have been written by V. I. Vernadsky in the last years of his life and published many years after his death: *The Chemical Structure of the Biosphere and Surroundings of the Earth,* published in 1965, and *Scientific Thought as a Planetary Phenomenon,* published in an abridged form in 1977, and completely only in 1991. The present book is the translation of this latter edition. As an appendix to the monograph, we apply the English version of Vernadsky's publication which was last in the lifetime. It was translated by his son Georgii, professor of Yale University and published in the journal "American Scientist", 1945, Vol. 33, no. 1, under the title "Biosphere and Noosphere". Also appended is the chronological record of the principal events of his life and activity.

Being V. I. Vernadsky's highest achievement, the biosphere doctrine left its time behind and never got a just appreciation from the contemporaries. After V. I. Vernadsky's decease, many papers appeared concerning his activities in mineralogy, crystallography, geochemistry, history of scientific knowledge, but his biosphere doctrine was mentioned by none during several decades.

The situation abruptly changed in the 1970s, when the demographic explosion and scientific-technological revolution led to a dangerous pollution of the environment of man. The danger was so great that scientists, politicians, and businessmen began to speak and write about the biosphere. Academician B. S. Sokolov, an eminent Russian geologist and palaeontologist, was quite right when he wrote (as early as in 1985) that now "biosphere as a whole and its various aspects—scientific, technological, social, philosophical, and prognostic—are dealt with in hundreds of thousands publications, in thousands scientific sessions, conferences, and symposia of every rank and scope, in numerous and diverse research programs, both national and international. It will be no exaggeration to assert that the idea of the biosphere occupies one of the central places both in the modem natural science and in the life of the contemporary human society[3].

It was this outburst of the interest to the biosphere that caused one to recollect all what was written about it by V. I. Vernadsky. Many tens of articles about this V. I. Vernadsky's doctrine were published in Russia. The information about him began to penetrate also into other countries. As early as in 1968, the UNESCO organized a conference of the governmental experts on the theme: "The scientific foundation of the rational use and conservation of the resources of the biosphere". The Russian scientists V. A. Kovda and V. E. Sokolov took part in the conference. Owing to them, the participants acknowledged that V. I. Vernadsky is the author of the conception of the biosphere, and took his ideas as a base for recommendations in the field of the coordinated action in environment protection. The resolutions of the conference led to the establishment of a continuous program "Man and biosphere", approved by the UNESCO in 1970.

After the Paris conference, V. I. Vernadsky's name began to be mentioned in many articles of that flow of the ecological and futurological literature which arose in all advanced countries beginning from the 1970s.

This process was stimulated by H. C. Hutchinson's book *Biosphere,* where the author set forth the content of the early works by V. I. Vernadsky dealing with this envelope of the Earth. He considers these words in some detail, and gives them a high estimate.

In 1979, in Oxford, a book *Geia: A New Concept of the Life Development on Earth* appeared, written by an English physicochemist James Lovelock. In this book of interest, the author develops the views very similar to the early V. I. Vernadsky's concepts on the biosphere, without even mentioning his name. J. Lovelock also advances the idea on the close interaction between

[3] *B. S. Sokolov. Biosphere: Concept,Structure,Evolution. V I. Vernadsky and Our Times. Moscow: Nauka, 1986, p. 98.*

the organic world and the inorganic natural environment which surrounds this world. In 1983, J. Lovelock published a special paper dealing with the influence exerted by the living substance upon the atmosphere composition. Lovelock's conclusions are identical to those made by V. I. Vernadsky as early as in the 1920s.

In J. Lovelock's later works (after he has read the above mentioned book by G. C. Hutchinson and the abridged English version of V. I. Vernadsky's *Biosphere)* the closeness of the author's views to those of V. I. Vernadsky is emphasized. He calls V. I. Vernadsky a great predecessor. He speaks about it in most detail in a small paper *Prehistory of Geia,* published in 1986. In this paper he writes: "Vladimir Vernadsky was the first to make a conclusion that the living organisms take part in the rotation of elements. He clearly recognized that there is a connection between the life on the Earth and the physical environment. In the Soviet Union Vernadsky is acknowledged as a great scientist. We, the scientists of English-speaking countries, also must admit the outstanding services of V. I. Vernadsky before science".

It is to be noted that Lovelock and other English-speaking authors only knew the earliest biospherical works of V. I. Vernadsky. Lovelock never read the late works by V. I. Vernadsky (which far amplify and modify his original ideas) for these works have not been translated into English.

At the same time, the early works of V. I. Vernadsky on the biosphere, including his monograph *Biosphere,* contain (besides the exceptionally valuable conclusions and generalizations) also a series of erroneous statements. For example, he considered the living substance to be radically distinct from the non-living one and never to be generated on the Earth abiogenetically. Therefore, he adhered to the principle *omnevivum e vivo* ("all living from the living"), advanced in 1668 by Francesco Redi, a Florentine physician. V. I. Vernadsky considered life to be eternal and accepted a hypothesis of the Swedish scientist Svante Arrhenius, according to which life came to the Earth (in the form of spores) from the cosmos, most probably from Venus, driven by the solar wind. The surface temperature of Venus was then erroneously thought to be
50-60°C (after the spectroscopic data) which suggested the existence of life upon this planet. V. I. Vernadsky thought that life got

to the Earth as a set of simplest forms, later on it rapidly covered all the surface of the Earth and created the biosphere. Afterwards, the living substance only developed morphologically, while neither its mass nor its average chemical composition underwent any change during all geological history of the Earth. In this connection, V. I. Vernadsky supposed that the Archean rock-weathering and soil-forming processes were identical to those in the contemporary epoch. He assessed the technological activities of the mankind as a huge geological and geochemical force alien to the biosphere and superimposed upon its permanent existence.

F. T. Yanshina in her monograph *The Evolution of V. I. Vernadsky's Views on the Biosphere and the Development of the Noosphere Doctrine* (1996) has shown that V. I. Vernadsky had given up these concepts (certainly erroneous from the contemporary viewpoint) resolutely since the mid-1930s. This fact had not been taken into account by the earlier investigations of V. I. Vernadsky's heritage.

To the mid-1930s, the chemists of many countries learned to obtain the various compounds (aminoacids, ketones, porphyrines) artificially from a mixture of carbon dioxide, marsh-gas, and ammonium hydrate, acting upon this mixture by slow heating or electric current. These experiments destroyed the impassable barrier between the living and non-living substances. This fact changed V. I. Vernadsky's views abruptly.

F. T. Yanshina showed (in the above-mentioned monograph) that in V. I. Vernadsky's works written after the mid-1930s the idea of the eternity of life is rejected. He recognized the appearance of life on the Earth by means of abiogenesis, which latently is going on even nowadays. He came to a conclusion that during the geological history the mass of the living substance increased and its average chemical composition repeatedly changed. In other words, in the mid-1930s V. I. Vernadsky acknowledged the evolution of all components of the biosphere. His biosphere doctrine only benefited by this and became more perfect.

Having accepted the idea of the evolution of the biosphere, V. I. Vernadsky also changed his viewpoint upon the technological activities of the mankind. He came to consider them as a law governed evolutionary stage in the development of the biosphere. He believed in the strength of the human reason and supposed that the team scientific thought will overcome the negative results of the technogenesis and will secure, in future, the rational transformation (and not annihilation) of the natural components of the biosphere, for a maximum satisfaction of the material and spiritual demands of the mankind which is growing quantitatively. This future evolutionary state of the biosphere of the Earth was designated by V. I. Vernadsky *noosphere,* the sphere of reason (the term introduced as early as in 1922 by a French philosopher and mathematician Edouard Le Roy).

V. I. Vernadsky intended to elaborate the noosphere doctrine in more detail, but he had no time to answer. Still in his article *Several Words on the Noosphere* (1944; the last paper out of all those which he published during his life) and in the two above- mentioned posthumous monographs, conditions are formulated which ought to be kept for the creation of the noosphere (after V. I. Vernadsky's opinion). These conditions are:

1. Peopling of all the Earth.
2. Abrupt transformation of the means of communication and commerce between different countries.
3. Establishment of political and other ties between all the states of the Earth.
4. Predominance of the geological role of man over other processes which take place in the biosphere.
5. Expansion of the frontiers of the biosphere and the man's exit into the Cosmos.
6. Industrial exploitation of the new sources of energy.
7. Equality of the people of all races and religions.
8. Increase in the role of people's masses in the decisions on the questions of internal and foreign policy.
9. Freedom of scientific thought and scientific search from the pressure of religious, philosophical, and political considerations, and the creation of the conditions, favorable for the free scientific thought, in social and state structure.
10. Rise of the well-being of the world's people. Creation of a real possibility to exclude malnutrition, hunger, misery, and to weaken the influence of the diseases.

11. Rational transformation of the original nature of the Earth, with the purpose to make it capable to satisfy all material, aesthetic, and spiritual demands of the mankind.
12. Exclusion of wars from the life of society.

It is easy to see that now, after the expire of half a century of the formulation of these conditions by V. I. Vernadsky, they are for the most part carried into effect or at least are being in the process of realization, which brings the mankind nearer to the creation of the noosphere.

It is also easy to see that these conditions are very close to those accepted as necessary by the International United Nations Conference on Environment and Development, June, 1992, Rio de Janeiro and listed in the main concluding documents of this conference, *Route to the 21th Century.* Therefore it is no wonder that the "Conception of the transition of the Russian Federation to the way of sustainable development" (confirmed by the decree of the President of Russia B. N. Yeltsin in April, 1996) ended with the following words: "The movement of the mankind to the sustainable development will finally lead to the forming of the sphere of reason (noosphere) predicted by V. I. Vernadsky when spiritual values and knowledge of Man living in harmony with his environment will become the criterion of the national and individual richness".

It remains to say several words on the book presented to the reader's attention. Its main text was written by V. I. Vernadsky in 1937-1938, but in the subsequent years, during World War II, he continued to make corrections and supplements to the book. It was first published in 1986, with large cuts. For the second time, it was published in 1988, without cuts, in the collection of V. I. Vernadsky's *Philosophical Thoughts of a Naturalist.* For the third time, it was published in 1991 as a monograph, after the additional collation with the author's manuscript being kept in the Archive of the Academy of Sciences. It is difficult to characterize the content of the book in short. It is far more extensive than its title, although the idea of the world significance of the scientific thought permeates it from the beginning to the end and ties up all its parts together. This book may be considered as an introduction to the teaching about the noosphere. The book gives much con sideration to the analysis of this concept. Beside that, it outlines in broad touches, the part played by the mankind in the transformation of the biosphere. The book gives a general concept of the living substance and its organized state, of the evolution of the biosphere, and the inevitability of its evolutionary transformation into the noosphere; on the conditions necessary for such transformation; on the main stages of the development of culture; on the further fate of the noosphere; on the biogeochemistry as the main scientific direction in the study of the biosphere; on the differences between the living and non-living substance of this envelope of the Earth.

The present book holds a special position among the works of V. I. Vernadsky. It covers a very large range of questions and is specific with relation to its main topic. Nature, human society, scientific thought are treated by V. I. Vernadsky in their indissoluble integrity. *Scientific Thought as a Planetary Phenomenon* is an acme of V. I. Vernadsky's scientific work, a grandiose in its intention result of the author's reflections on the fate of scientific knowledge, on the interrelations between the sciences on nature and the philosophy, on the future of the mankind. It may be described as an unfinished synthesis of the ideas developed by V. I. Vernadsky during the final years of his life.

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Section one

SCIENTIFIC THOUGHT AND SCIENTIFIC WORK AS A GEOLOGICAL FORCE IN THE BIOSPHERE

CHAPTER I

The man and the mankind in the biosphere as a regular part of its living matter and its organization. Physical-chemical and geometrical heterogeneity of the biosphere: the radical difference in organization (with respect to matter and energy as well as to time) between its living and inert matter. Evolution of species and evolution of the biosphere. Manifestation of a new geologic force in the biosphere— that of the scientific thought of social humanity. This manifestation is related to the glacial period we are going through with one special geological phenomenon among many recurrent (in the history of our planet) phenomena which, as to their causes, are outside the Earth's crust.

1. Like all living, the man is not a self-sufficing, independent from the environment, natural object. However, nowadays even naturalists do not take it into account while contrasting a man and a living organism in general to their environment. As for contemporary scientists, the indissolubility of a living organism and its environment is unquestionable. It represents the starting point for the biogeochemist who aims at the understanding, expressing, and fixing of this functional dependence. Philosophers and the modem philosophy do not take into consideration (for the most part) this functional dependence. Philosophers and the modem philosophy do not take into consideration on (for the most part) this functional dependence (of a man as a natural object and the mankind as a natural phenomenon) upon the environment where they live and think.

Philosophy cannot take it into consideration adequately for it proceeds from the laws of reason which in any case is the ultimate and self-sufficing criterion for it, even in the cases when the scope of reason is, actually, limited, which takes place in religious or mystical

The present-day scientist proceeding from the recognition of the real existence of his environment (of the world to be studied: the nature, the space, or the world reality)[1] cannot hold this philosophical view as a starting position for scientific work.

For nowadays the scientist knows exactly that the man does *not* live over a structureless surface of the Earth, is *not* immediately tied up with the space in a structureless nature. True, owing to the usual routine and the influence of philosophy, this fact is often forgotten even by a modem naturalist who penetrates into the nature deeply: he ignores this fact, does not make it out distinctly.

The man and the mankind are first of all, and most closely, linked with the living matter populating our planet. By no real physical process can they be separated from it. Such separation is possible in thought alone.

2. The concept of life and living is clear to us in our daily round and never raises a scientifically serious doubt (with relation to is real manifestations and the corresponding natural objects). It is only in our century, after the filterable viruses had been discovered, science obtained facts making us for the first time ask seriously, scientifically and not philosophically, whether we deal with a living natural matter or with an inert, abiotic one. With reference to viruses, the doubt is caused by the scientific observation and not by a philosophic idea. This is wherein the great scientific meaning of virology consists. This discipline is today on the right track. The doubt will be solved in future and will lead to nothing but a more exact concept of *a living organism*: cannot fail to lead, under such an approach...

However we come across other doubts in *science,* provoked by philosophical and religious quests and striving for new ways. For example, the Bose Institute in Calcutta is making research into the

[1] Here and elsewhere I shall speak of reality instead of the nature or the space. Taken in its historical aspect, the concept of nature is a sophisticated idea. Very often it includes the biosphere alone and it is more suitable to use it precisely in this sense—or not to use at all (§ 6). Historically, this will correspond to the prevailing majority of cases when this idea was used in natural sciences and literature. The concept of “space” would be perhaps more applicable solely to that part of reality which is reflected by science. In this case, the philosophical pluralistic representation of reality becomes possible, without any unified criterion for “space”.

phenomena whose manifestations in the material-energy environment are philosophically *common* to the living and abiotic natural bodies. In the abiotic bodies, these phenomena are but slightly manifested, while in the living ones, they are clear and evident; but they are inherent in both cases.

Even if this area of the phenomena common to the abiotic and living natural bodies exists in the form tentatively described by Bose, this fact would not at all lessen the patent distinction between the abiotic and the living. Such distinction must turn up in this area as well in its existence is proved anyhow.

One only ought to proceed in the study of the phenomena at another angle, not in the light in which Bose treated them, not as the *life* phenomena but as those of living natural bodies, *of the living matter.*

To avoid any misunderstanding, in the future account I shall refrain from using the terms “the life”, “the living”. For should we proceed from such concepts, we would go far beyond the limits of the life phenomena as studied by science and intrude either into a field alien to science, into the field of philosophy, or (like the Bose Institute does) into a new field of new manifestations of matter and energy common to all natural bodies of the biosphere. This new field far exceeds the boundaries of the topic that interests us now, that is, of the main problem of the living organism and the living matter.

Thus I shall avoid the terms and concepts “the life” and “the living” and narrow my research area to the ideas of *“the living natural body"* and *“the living matter”*. Every living organism in *the biosphere* (a natural object) is a living natural body. *The living matter of the biosphere is the totality of the living organisms inhabiting it.*

Thus defined, ‘the living matter” is a completely exact notion entirely embracing the objects studied by biology and biogeochemistry. This notion is simple and clear and causes no misunderstandings. In science, we only study the living organisms and their communities, which present a scientific equivalent of the idea of life.

3. The man as any other living natural (or real) body is inseparably linked to a certain geological envelope of our planet, with the biosphere, noticeably differing from its other envelopes. The struc-

ture of the biosphere is defined by its peculiar *state of organization.* Being an isolated part of the whole, the biosphere occupies a regularly fixed place within the planet.

The living matter, just like the biosphere, possesses a peculiar organization and may be considered as-a regularly fixed *function of the biosphere.*

Organization is not a mechanism. It is clearly distinct from a mechanism in its being always in the process of formation; the smallest matter and energy particles involved in it incessantly move. With respect to time (in the generalizations of mechanics and in a simplified model) we may define the organization by that none of its points (either material or energetic) returns regularly: none of them ever gets in the same biosphere point where it once had been. Such return may only occur as a result of contingency of a very small probability.

The biosphere as an earth envelope embracing the whole globe is sharply outlined and its dimensions are substantially conditioned by the existence of the living matter in it: it is *populated* by the living matter. There is an unceasing exchange of matter and energy between the abiotic, inert part of the biosphere, its inert natural bodies and the living matters populating it. The matter exchange is implemented through the atomic movement caused by the living matter. In the course of time, this exchange manifests itself by the regularly shifting (ever striving for stability) *equilibrium.* It permeates the whole biosphere, and this *biogenic flow of atoms* creates the latter, to a significant degree. In this way, during all the geological time, the biosphere remains inseparably and continuously linked to the living matter which populates it.

The planetary, cosmic significance of the living matter manifests itself just in this biogenic flow of atoms and in the energy involved in it. For the biosphere is the only envelope of the Earth into which the cosmic energy and cosmic radiation permanently penetrate. Cosmic radiation, first of all the solar one, supports the dynamic equilibrium and the organization between the biosphere and the living matter.

From the geoid level, the biosphere stretches up to the limits of the stratosphere and penetrates it, but it can hardly reach the ionosphere, the Earth’s electromagnetic vacuum, which only recently had revealed itself to the scientific knowledge. Beneath the geoid level, the living matter penetrates the stratisphere and the upper portions of the metamorphic and granite envelopes. If one makes a cross-section of the globe, one would see that the living matter rises 20-25 km over the geoid level, and sinks, on the average, 4-5 km below it. These boundaries change with time and at places may advance far beyond these limits, although this occurs only within small areas. In deep seas, the living matter certainly goes deeper than 11 km here and there, and its presence at a depth exceeding 6 km has been demonstrated by observations[2]. As to the stratosphere, we witness man's penetrating it, but the man is always inseparable from other organisms—insects, plants, microorganisms—and thus the living matter has advanced to more than 40 km above the geoid level and goes on rising rapidly.

In the course of the geological time, one may observe the process of continuous expanding of the biosphere frontiers and its colonization by the living matter.

4. *The organized state* of the biosphere, or the organization of the living matter, must be viewed upon as dynamic equilibria oscillating about an average distinctly expressed both in the historical and geological time. Displacements or oscillations of the average itself are continuously manifested in the geological time, not in the historical one. During the geological time, in the circular processes characteristic of the biogeochemical organization, no point (be that an atom or a chemical element) ever returns in aeons of centuries identically-to its previous position.

This salient feature of the biosphere has been strikingly and dramatically expressed by Leibnitz (1646-1716) in one of his philosophical discourses which seems to be his *Theodicy.* He recollects there how, in the late 17th century, he was taking a walk in a large garden, in a company of high society persons. Having spoken about the infinite diversity of nature and about the infinite efficiency of mind, Leibnitz indicated that one never finds two leaves of a tree or herb that would be fully identical to one another. Of course, all

[2] The benthic living organisms have been really found at all depths of the World Ocean, including those exceeding 11 km (see the monographs by G. M. Belyaev. *The Fauna of the Ultraabyssal Zone of the World Ocean*, Moscow, Nauka, 1966; *The Deep-Sea Oceanic Trenches and Their Fauna,* Moscow, Nauka, 1989)—Edit. note.

attempts of the numerous society to find identical leaves remained futile. In that case Leibnitz reasoned like an erudite who had snatched the phenomenon out of his books rather than like a nature observer who had just discovered it. One might trace precisely this example with the leaf back to the philosophical folklore of the previous centuries[3].

In everyday life, one may see the same nonidentity phenomenon in *personality*: there cannot exist two identical individualities indistingiushable from one another. In biology, the same phenomenon may be derived from the *chemical distinction* of any average *individual* of the living matter from other ones. Both in its chemical combinations and, evidently, in its chemical elements each individual possesses certain peculiar features of its own.

5. *The physical-chemical and geometrical (§ 47) heterogeneity* is extremely characteristic of the structure of *the biosphere*. The latter consists of the living and inert matters, which, in the course of the geological time, remain clearly distinct in their genesis and structure. The living organisms, i.e. the whole living matter, originate from the living matter and in the course of time form generations that never emerge directly from any abiotic matter of the planet outside another similar living organism. Still there is an incessant, never interrupted connection between the inert and the living matter. This connection may be characterized as a continuous biogenic flow of atoms from the living matter into the inert matter of the biosphere, and backwards. This biogenic flow of atoms is called forth by the living matter and evidenced by the never ceasing processes of breath, nutrition, reproduction, etc.

In the biosphere, this continuous (lasting throughout the entire geological time) heterogeneity of its structure is the main prevailing factor sharply distinguishing it from all other envelopes of the planet.

The heterogeneity penetrates (deeper than the phenomena usually studied by the natural sciences) into such properties of space and time to which scientific thought approaches only in our times, in the 20th century.

This living matter embraces all the biosphere, creates and

[3] See, for example, Lucretius Carus, *On the Nature of Things,* Book 2, Moscow, 1913, p. 54—Edit. note.

changes it, while with respect to weight and volume, it makes up but a small portion of it. The abiotic, inert matter markedly prevails. With respect to volume, the utterly rarefied gases predominate; with respect to weight, the solid rocks and, to a lesser degree, the fluid component: the saline water of the World Ocean. The living matter, even in its greatest concentrations in exceptional cases, and in minor parts of the biosphere, does not constitute more than several tens per cent of the volume of the matter of the biosphere. As to the weight, the living matter averages from one to two hundredth per cent. However, geologically, it is the greatest biosphere force and determines, as we shall see, all processes in the biosphere, developing huge free energy and generating the main geologically evident force in the biosphere. We cannot yet measure this force quantitatively, but, perhaps, it exceeds the force of any other geological phenomena in the biosphere.

It would be suitable to introduce, in this relation, some new basic concepts to deal with them further on.

6. These concepts are linked up with the idea of a natural body or a natural object, as well as with the idea of a natural phenomenon (all of them being often generalized in the notion of a real body or a real phenomenon).

The living matter is a natural body or phenomenon in the biosphere. The conceptions of a *natural body* or a *natural phenomenon* have been but little investigated in logic. Nonetheless, they represent the basic conceptions of the natural science. For our purpose, we do not need to delve deeply into their logical analysis. They are the *natural objects,* i.e., the bodies or phenomena formed by the natural processes.

Not only living organisms and living matters represent the natural bodies of the biosphere. The bulk of the biosphere matter consists of inert bodies or phenomena which will be called here the *abiotic* bodies. Such are, for example, gases, atmosphere, rocks, chemical elements, atoms, quartz, serpentine, etc.

In the biosphere, apart from the living and abiotic 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 abiotic natural bodies forming complicated abiotic-living structures. I shall call these complicated natural bodies *“living-abiotic natural bodies* The biosphere itself is a complex planetary living - abiotic natural body. As we shall see, the distinction between the living and abiotic natural bodies is so great that in the Earth processes one never observes a transition of one of these categories into another. We never and nowhere observe such a transition in our research work. We shall also see that this transition is only thinkable at a level more profound than the level of the known physical-chemical phenomena.

The main manifestation of this dichotomy is the involved *heterogeneity of the structure of the biosphere* and a sharp distinction between the living and abiotic natural bodies within the matter and the energetics of the biosphere.

7. One of the manifestations of such heterogeneity of the biosphere consists in the fact that the chemical processes in the living matter, being assessed in their temporal aspect, take altogether different course as compared with the processes in the abiotic matter. In the living matter, the processes take place at a *historical time* scale; in the abiotic matter, at a *geological time* scale, whose “second” is much less then a decamiriade (which equals to 100 thousand years of the historical time)[4]. Outside the biosphere, this difference turns out to be still more clear-cut, and, in the lithosphere, one observes an organized state of the bulk of its matter. Under this state, the majority of atoms are immobile (as the X-ray methods show) and do not evidently change their place through tens of thousands decamiriades, which is the time interval now accessible to our measurement.

Still recently, the geology was dominated by an idea that geologists can not recognize the manifestations of slow geological changes that had taken place during the epoch of the man’s existence. In the times of my youth, one learned and thought that, as a rule, the climate, the mountain structures, the species of organisms do not change in the course of a geological study, are not *current affairs* for a geologist. Now this ideological situation, essential for a naturalist, has changed abruptly, and we see the action of the surrounding geological forces more clearly and intensely. It is hardly an accident that this change coincided with the growth (in scientific

[4] On the decamiriades, see: V. I. Vernadsky, *On Some Topical Problems in Radiogeology,* Izvestiya AN, 7th series, OMEN, 1935, no. 1, pp. 1-18.

consciousness) of the belief in the geological significance of *Homo sapiens*; with the discovery of a new biosphere state, noosphere, being one of the forms in which this state expresses itself. This discovery is certainly related to the growth of precision of the natural science research and thought, within the limits of the biosphere where the living matter plays the main role.

The sharply distinct manifestations of the living and the inert features in the biosphere, in their temporal aspect, though important, serve a particular expression of a much more general phenomenon which is reflected in the biosphere at every step.

8. The living matter of the biosphere is sharply distinct from its abiotic matter in two main processes of a great geological importance which give a very peculiar appearance to the biosphere, nonexisting in any other planetary envelope. Both processes solely manifest themselves against the background of the geological time. They may cease sometimes but they never take the reverse course.

First of all, with geological time *the power of the revelation of the living matter in the biosphere increases.* The importance of the living matter in the biosphere and its influence upon the inert matter of the biosphere become more significant. This process has still received but little attention. Further, I shall deal with it all the time.

Much more attention was paid to another process, which was much more studied, widely known and most deeply imprinted on the entire scientific thought of the 19th and 20th centuries. This is the process of *species evolution* in the course of geological time: the process of radical changes of the living natural bodies themselves.

It is only in the living matter that we observe a sharp change of the natural bodies themselves in the course of geological time. Some organisms transform into others, die (as well call it), or change in a radical way.

The living nature is *plastic.* It alters, gets adjusted to the environmental changes, but perhaps has its own evolutionary process as well, manifesting itself in the changes on the geological time scale, independently from the environmental changes. Probably, this is evidenced by an incessant and intermittent growth of the central nervous system of animals in the course of the geological time; by the importance of this system for the biosphere;

and by deep reflection (owing to the nervous system) of the living matter[5] in the surrounding world, by its (the living matter's) penetration into it (surrounding world).

Evidently, the plasticity of the living matter is a very complex phenomenon, for organisms exist which apparently do not change their morphological and physiological structure during hundreds of millions years, up to five hundred of millions and more, in the course of countless generations. They are so called *persistents,* the phenomenon which unfortunately remains very poorly studied in biology. Still we observe a phenomenon common for the living matter; the *plastic evolutionary* process which is completely absent in the inert natural bodies. For the latter, we see *now* the same minerals, the same processes of their formation, the same rocks, etc., that were *two billion years ago.*

Incessantly, during all the geological time, the evolutional 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.

Owing to the species evolution which proceeds incessantly and never stops, the reflection of the living matter into the environment changes abruptly. Because of it, the process of evolution (alteration) is transferred over the natural bio-inert and biogenic bodies playing the most important part in the biosphere; among them are such bodies as soils, surface and ground water (seas, lakes, rivers, etc.), coal, bitumens, limestones, organogenic ores, etc. For example, the Devonian soils and rivers are not the same as the soils and rivers of the Tertiary or of our epoch. This is an area of new phenomena hardly taken into account by scientific thought. *The evolution of species turns into the evolution of the biosphere.*

9. The evolutionary process acquires a special geological

[5] An incessant (during the whole geological history of the biosphere) evolution of the nervous tissue was repeatedly indicated, but never, as far as I know, profoundly scientifically and philosophically analyzed. Because here we do not deal with hypotheses, nor with pure theories, we cannot deny the fact of its evolution. We can only question its interpretations. The acceptance of Redi principle limits the number of explanations.

significance because it has created a new geological force: the scientific thought of the social humanity. Now we witness its manifest entering the geological history of our planet. During the recent millenia, one observes an intense growth of influence of the living matter of one species (the civilized humanity) upon the shift of the biosphere condition. Under the action of scientific thought and human labor, the biosphere goes over to a new state—to *the noosphere.*

Due to regular movement which lasted one-two millions of years (at a rate constantly accelerating in its manifestations), the humanity embraces the whole planet and becomes separated (isolated) from the other living organisms as a new and unprecedented geological force. In this way, at a rate comparable to that of reproduction, which is expressed by a geometric progression with time, an incessantly growing set of *new (for the biosphere)* inert natural bodies and new great natural phenomena is created in the biosphere.

Before our eyes, the biosphere changes sharply. And there can hardly be any doubt that its reconstruction (which is being manifested in this way by scientific thought, through the organized human labor) is not an occasional phenomenon depending upon the will of man, but an elementary *natural process* whose roots are deep and were prepared by an evolutionary process which has lasted for hundreds of millions of years. >

When the man is guided by a scientific (and neither philosophical, nor 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 an inevitable manifestation of a great natural process having lasted in a regular way for at least two billions of years.

At present, under the influence of the surrounding horrors of life, we often hear about the downfall of civilization, about the self- destruction of humanity, and that along with an unprecedented blossoming of scientific thought. These attitudes and these judgments seem to be a consequence of an insufficiently deep penetration into the surrounding world. Scientific thought is not yet embodied in life; we live under the influence of philosophical and religious habits still persisting but irrelevant to the present day realities.

Scientific knowledge, manifesting itself as a geological force creating the noosphere, cannot lead to the results contradicting the geological process that had created it. It is not an incidental phenomenon: it is very deeply rooted.

10. This process is tied up with the origin of the human brain. In science history, this process was discovered (in the form of an empiric generalization) by the profound American naturalist, eminent geologist, paleontologist, and mineralogist, J. D. Dana (1813-1895), in New Haven. He published his conclusions as far as 80 years ago. Strangely enough, this generalization still remains unrealized and rather forgotten. It was not appropriately developed.

I shall speak about this later. Here, I may note that Dana presented his generalization in a philosophical and theological language, and that it seemed to be tied up with now inadmissible (scientifically) ideas.

Putting it in the current scientific language, Dana has noted that in the course of the geological time, a certain part of the planet's inhabitants acquire more and more perfect (as compared to the earlier stages) central nervous apparatus—the brain[6]. Dana called this process *encephalosis*. It never turns back, though repeatedly stops, sometimes for millions and millions of years. Therefore, this process manifests itself through the polar time vector whose direction never changes. We shall see that the geometrical state of the space occupied by the living matter is characterized just by the polar vectors and there is no place for straight lines.

The evolution of the biosphere is linked with the *acceleration of the evolutionary process* of the living matter.

We know nowadays that there are critical periods in the history of the Earth's crust when the rate of geological activity in its various manifestations becomes accelerated. This acceleration is certainly not manifested in the historic time and may be scientifically fixed only at a geological time scale.

One may consider these periods to be critical in the history of the planet, and all indicates that they are caused by deep (in relation to the Earth's crust) processes apparently transcending the limits of the Earth's crust. At the same time, the volcanic, orogenic, and

[6] In the manuscript: "Expressing it in current scientific language, Dana has noted that, in our planet, with the course of the geological time a more and more perfect central apparatus—*the brain*—of a certain part of its habitants is manifested; as compared with that having existed before.

glacial phenomena become intensified, as well as marine transgressions and other geological processes covering the major part of the biosphere, simultaneously and throughout it. The acceleration and the greatest changes of the evolutionary process coincide with these intervals. During these periods, the greatest and the most important changes in the structure of the living matter take place, providing an evident manifestation of the profoundness of the geological significance of this plastic reflection of living matter against the planetary changes.

There is no theory, no exact scientific explanation for this main phenomenon in the history of our planet. The idea has been created empirically and subconsciously, it got into science imperceptive. Its history has never been written. This phenomenon has been much studied by the American geologists, particularly by J. D. Dana. The scientific thought of our century has been very stimulated by this phenomenon.

But it must and can be approached quantitatively. One can measure its geological duration and thus numerically characterize the change in the rate of the geological processes. This is one of the immediate tasks of radiogeology.

11. Before this task is solved, we must note and take into account that the process of the evolution of the biosphere and its transformation into the *noosphere,* clearly reveals the acceleration of the rate of the geological processes. The earlier history of the biosphere did not know such changes as those having taken place in the biosphere during the past few *thousand years* in the connection with the growth of scientific thought and social activities of the humanity.

At least, such are the concepts that we can now infer from the study of the evolution of the organisms in the course of the geological time. For the geological time, one decamiriade is far less than a second for the historical time. Therefore a thousand years at the historical time scale is less than 300 million years at the geological time scale. This does not contradict those great biosphere changes that took place, for example, in the Cambrian, when the calcareous skeleton elements of the macroscopic marine organisms emerged; or in the Paleocene, when the mammalian fauna was formed. We should not forget that the time when we live corresponds geologically to the critical periods of the above type, for the glacial period is not finished yet: the rate of changes is still so low that the humanity does not notice these changes.

The man and the mankind, the man's realm in the biosphere lie entirely within the limits of this period and do not exceed them.

One may give a picture of the evolution of the biosphere beginning from the Algonkian, more clearly from the Cambrian, during 500-800 million years. Not once the biosphere turned into a new evolutionary state; new geological manifestations, never having existed before, emerged. For example, in the Cambrian, when large organisms with calcareous skeletons originated, or in the Tertiary (perhaps in the Late Cretaceous), 15-80 million years ago, when our forests and steppes formed and when big mammalians came into existence. We are living now (during the past 10-20 thousand years) in an analogous period when man, having elaborated the scientific thought in his social environment, creates a new geological force in the biosphere, previously absent there. The biosphere has been turned or is rather turning into *a new evolutionary state—the noosphere*—is being conversed by the scientific thought of the social mankind.

12. The irreversibility of the evolutionary process is a result of a characteristic distinction of the living matter in the geological history of the planet from the inert natural bodies and processes of the planet. One may see that the irreversibility is tied up with the special qualities of the space occupied by the bodies of the living organisms, with a special geometrical structure (as P. Curie said), a special *space state.* In 1862, Louis Pasteur was the first to understand the radical importance of this phenomenon named by him, unhappily, "dissymmetry"[7]. Pasteur studied this phenomenon at another angle, in the inequality of the sinister and dextral manifestations in the organism, in the relation to the concepts of the "right" and "left" for organisms[8].

[7] The principle of dissymmetry has been formulated by P. Curie (1859-1906), but has been well and intuitively understood and expressed by L. Pasteur (1822-1895). I identified this principle here as a special one (L. Pasteur, *Oeuvres,* vol. 1, Paris, 1922; P. Curie, *Oeuvres.* Paris, 1908).

[8] It is strange that the "right-left" phenomenon has remained outside the philosophical and mathematical thought although some great philosophers and mathematicians, for example, Kant and Gauss, approached it. Pasteur was a perfect innovator in thinking, and it is very important that he studied this phenomenon and recognized its significance proceeding from experience and observation. Curie based his views on the ideas of Pasteur but developed them from the physical viewpoint. As to the significance of those ideas for life see: V. I. Vernadsky, *Biogeochemical Essays* (1922-1932), Moscow-Leningrad, 1940; V. I. Vernadsky. *Problems of Biochemistry,* Vol. 1, Moscow-Leningrad, 1935.

Geometrically, the rightness and the leftness cannot appear but in a space with polar and enantiomorphic vectors. The absence of straight lines and a clearly manifested curvature in the forms of life seem to be connected to the geometrical property. I shall return to this topic later, but now I must note that the space within the organisms does not correspond to Euclidean space (but corresponds to one form of Riemann space).

Now we have a right to admit (for the space we live in) the manifestation of the geometrical properties answering all three forms of geometry: Euclidean, Lobachevskian, and Riemannian. This inference is logically completely valid, but a further study is needed for understanding whether it is true[9]. Regretfully, a host of empirical observations related to this area and scientifically established is not assimilated (as to its significance) by the biologists and did not enter their scientific world outlook. Nevertheless, as it was shown by P. Curie, such special state of space cannot arise in a usual space without special circumstances. Using his terms, a dissymetric phenomenon must always be caused by a likewise dissymmetric cause. This corresponds to the basic empirical generalization, that the living takes its origin in the living and that any organism is born from another organism. Geologically it becomes apparent from the fact that there is an impassable border between the living and inert natural bodies and processes which is not observed in other Earth's envelopes. The biosphere includes two environments which are clearly distinct, both materially and energetically, mutually interpenetrating, and changing the atoms that make them up, connected with the biogenic flow of chemical elements. Below I shall return to this phenomenon in more detail.

[9] The mathematical thought has long ago acknowledged the similar admissibility of the search, in the surrounding reality, for the manifestations of the non- Euclidean geometries. Perhaps this thought was clear to Euclides himself when he separated the postulate of the parallel lines from the axioms. Lobachevsky (1793-1856), proceeding from the rejection of that postulate, tried and proved that the non-Euclidean geometry in our physical environment, this issue raised no doubt in the thought fermentation caused by A. Einstein (compare: A. Einstein, *Geometrie und Erfahrung; erweiter 'e Fassung des Festvortrages,* Berlin, 1921). One might object that in these cases there was admitted, *tacito consensu,* that some or other geometry is common to the reality as a whole, while in the given case we deal with the geometrical heterogeneity of space in our reality. The space of life differs from the space of inert matter. I see no reasons to suppose that such an admission contradicts the foundations of our exact knowledge.

13. Now we are witnessing an extraordinary display of the living matter in the biosphere genetically related to the appearance of *Homo sapience* hundreds of thousand years ago, with the creation, owing to that, of a new geological force, *scientific thought,* which has greatly increased the influence of the living matter in the biosphere evolution. Being embraced by the living matter, the biosphere seems to increase its geological force to an infinite degree; it seems also to become transformed by the scientific thought of *Homo sapiens* and to pass to its new state—*noosphere.*

The scientific thought as a display of living matter *cannot be,* in its very essence, a reversible phenomenon. It may stop in its movement, but having once arisen and revealed in the biosphere evolution, it bears in itself a possibility of unlimited development with time. It has been noted long ago, that in this relation the progress of scientific thought, for example, in the creation of machines, is completely analogous to the course of the reproduction of organisms.

There is no irreversibility in the inert biosphere environment. Here, the reversible circular physical-chemical and geochemical processes evidently prevail. The living matter intrudes them through its physical-chemical manifestations as a discord.

The growth of scientific thought, closely tied up with the growth of the peopling of the biosphere by man, through his reproduction and his breeding of the living matter in the biosphere, must be restricted by the environment alien to the living matter and exert a *stress* upon it. For this growth is tied up with the quantity of the rapidly growing mass of the living matter participating (directly or indirectly) in scientific work.

This growth and the involved stress constantly increase because this work includes the action of many man-created machines, whose multiplication in the noosphere is governed by the same laws as the reproduction of the living matter itself, i.e., this growth may be described by a geometrical progression.

Like the reproduction of the organisms manifests itself through the pressure of the living matter in the biosphere, the geological manifestations of scientific thought exert (by the tools it creates) a pressure upon the inert and restrictive (for thought) biosphere environment. Thus the noosphere, the realm of reason is created.

The history of scientific thought, scientific knowledge, and its historical development reveals itself in a new aspect, previously not recognized. This history ought not to be considered solely as a history of a humanitarian science. At the same time it is the *history of the creation of a new geological force in the biosphere—the force of scientific thought,* something not available earlier in the biosphere. This is the history of the manifestation of a new geological factor, a new expression of the organized state of the biosphere. This factor has formed spontaneously, as a natural phenomenon, during past several tens of thousand years. This history is not fortuitous, like any natural phenomenon, it is regular, like in the course of the time-dependent palaeontological process, which had created the brain of *Homo sapiens* and the social environment where (as its consequence, as a natural related process) scientific thought, this new geological and consciously directed force is being created.

But the history of scientific knowledge, even as the history of a humanitarian disciplines still remains unrecognized and unwritten. There is no attempt to do it. Only in the recent years the history of science begins to proceed beyond the "biblical" time for us; the existence of a *common centre* of its generation somewhere within the limits of the coming Mediterranean culture, 80 thousand years ago, begins being recognized. It is only with great gaps that we begin now to reveal through cultural remnants and to establish the unexpected or radically forgotten scientific facts which had been lived through by the mankind, and to make new empirical generalizations of them[10].

* 0 A rapid change in our knowledge owing to archaeological excavations permits us to hope for a very great progress in the nearest future.

CHAPTER II

Manifestation of the present historical moment as a geological process. The evolution of the species of the living matter and the evolution of the biosphere into the noosphere. This evolution cannot be stopped by the course of the universal history of the humanity. Scientific thought and everyday life of humanity as a display of the "biosphere to noosphere " evolution.

14. All consequences of the marvelous, unique times entered by the humanity in the 20th century are not yet vitally and mentally realized by us.

We live in a state of a breakpoint, in an exceptionally important and essentially new epoch of the life of the humanity, of its history on our planet.

It is for the first time that man embraced by his life and culture the whole outer envelope of the planet—all the biosphere in general, that is the part of our planet connected to life.

We are present and vitally participate in the creation of a new *geological factor* in the biosphere, the factor unprecedented with respect to its power and universality.

This factor is scientifically established for the past 20-30 thousand years, but it manifests itself most clearly and with an increasingly accelerating rate during the past thousand years.

Following many hundred years of the incessant spontaneous trends, the capture of all the surface of the biosphere by one social species of the animal kingdom *(by man)* is finished. There remains no site on the Earth inaccessible to man. There is no limit for his eventual reproduction. By his scientific thought and state- organized technology generated by this thought, by his very life, man creates a new *biogenic force* in the biosphere: the force directing his reproduction and creating favorite conditions for the settlement of man in such parts of the biosphere whereto his life (in some places, even any life at all) previously did not penetrate.

Theoretically, we do not see any limit for his potentialities, if only we do take into account the work of many generations. In the biosphere, any geological factor manifests itself in all its force solely in the action of the generations of the living beings during the geological time. Whereas under the rapidly increasing precision of scientific work (in this case, of the methods of scientific observation) we may now, as well as in historic time, establish clearly and study the growth of this new, essentially coming into being, geological force.

The humanity is a whole, and, though this fact is realized by the majority of the people, this wholeness is displayed through such forms of life which deepen and strengthen it practically imperceptibly for man, spontaneously, as a result of unconscious aspirations of the people towards this wholeness. Now the life of the humanity, heterogeneous as it is, became indivisible, united. An event having taken place in any remote part of any continent or ocean, is reflected and has major and minor consequences in many other places over the surface of the Earth. Telegraph, telephone, radio, aeroplanes, aerostats have covered the whole globe. The communications became simpler and faster. The degree of their organization rapidly improves, from year to year.

We can clearly see that this is the beginning of a spontaneous movement, the beginning of a natural phenomenon that cannot be broken off by any accidents in the human history. Here, perhaps for the first time, the relation of the historical processes to the palaeontological history of the manifestation of *Homo sapiens* becomes so vividly evident. This process of the *complete peopling of the biosphere* by man is conditioned by the course of the history of the scientific thought and tied up with the communication rate, with the achievements in the transport technology, with the possibilities of *momentary* thought transmission, due to which it may be discussed all over the Earth at the same time.

The struggle against this main historical trend makes even its radical adversaries to subdue to it. The state formations ideologically denying the principles of equality and unity of all persons try to stop spontaneous manifestations of these principles by all means, but there is no doubt that these utopian dreams can be soundly put into life. This will inevitably happen in the course of time, for the creation of the noosphere out of the biosphere is a natural phenomenon, basically deeper and more powerful than the human history. It demands the manifestation of the humanity as a single whole, which is its necessary premise.

This is a new stage in the history of the planet which does not permit us to use its historical past for comparison without some correction. For this stage creates something essentially new in the history of the Earth and not of the humanity alone.

It is for the first time that a man had recognized himself as an inhabitant of the *planet* and may (and must) think and act from another viewpoint—not solely from that of a separate personality, family, or kin, state, union of states, but also from the *planetary point of view.* Like all living beings, man cannot think and act from the planetary aspect except in the realm of life, in the *biosphere,* a certain Earth envelope with which man is inseparably connected, and out of which he cannot go. Man's existence is a function of the biosphere. He bears the latter with him everywhere. And he changes it inevitably, regularly, incessantly.

15. Simultaneously with the complete peopling of the surface of the biosphere by man, that is closely related to the progress of the scientific thought, i.e., to its progress with time, a scientific generalization arose in *geology* which explained the nature of the given stage in the history of the humanity in a new manner.

The geological significance of the humanity became understood by the geologists in a completely new fashion. True, the recognition of the geological importance of the human social life was voiced in the history of scientific thought long ago, though not in so a distinct form. It was in the beginning of our century, that Ch. Schuchert (1858-1942) in New Haven and A. P. Pavlov (1854-1929) in Moscow have independently taken into account geological changes (known long ago), which are brought about by the appearance of human civilization in the environment, in the image of the Earth. Schuchert and Pavlov held it admissible to take this manifestation of *Homo sapiens* as a basis for identifying *a new geological era,* along with the tectonic and orogenic data by which one usually defines such divisions.

They rightly tried to divide the Pleistocene on this basis, defining its end by the beginning of advent of (the last hundred or two hundred thousand years—approximately several decamiriades ago) and identifying a separate geological era: *psychozoic* (after Schuchert) or *anthropogenic* (after Pavlov).

Actually, Schuchert and Pavlov have deepened and made more precise an inference made much earlier which did not contradict the empirical scientific work. They put this inference into the framework of the divisions of the history of the Earth distinguished in the modem geology. Thus, this inference has been clearly recognized by one of the creators of the geology of our time, L. Agassiz (1807-1873), who proceeded from the palaeontological history of *life.* As early as in 1851, he fixed a special geological era of *man.*

Agassiz did not proceed from the geological facts, but, to a significant degree, he was guided by a common religious faith that was very strong in the pre-Darwinian natural science. He was guided by the idea of a special place occupied by man in the Universe[1].

The geology of the mid-19th century is incomparable with that of the early 20th century with respect to its strength and scientific soundness, and the era of man after Agassiz can not be scientifically compared with the era after Schuchert-Pavlov.

Still earlier, in the late 18th century, when geology was only shaping and its main concepts did not yet exist, the same idea of the geological era of man was expressed by G. Buffon (1707-1788). He was influenced by the Enlightenment philosophy and emphasized the meaning of Reason in the conception of the World.

A clear distinction between these verbally identical ideas is evident from the fact that Agassiz admitted the geological duration of the World, the existence of the Earth, to be equal to the Biblical span, six or seven thousand years; Buffon thought this duration to be more than 127 thousand years; Schuchert and Pavlov assumed it to be more than a billion years.

16. In philosophy, we long ago had similar ideas having resulting from another approach: not from scientific observation and experience, like that of Ch. Schuchert, A. P. Pavlov, L. Agassiz (and J. Dana who knew about Agassiz's generalizations) but by means of philosophical search and intuitions.

' This idea was formulated by Agassiz in a polemical work directed against the Darwinism (L. Agassiz, *An Essay on Classification,* London, 1859). Perhaps, this is why it has not gained such influence that it should have, in spite of many important considerations it comprised.

The philosophical representation of the world in its general outline and in particularities creates the environment wherein scientific thought exists and develops. To a certain (not insignificant) degree, this thought itself is a condition of its environment, while the achievements of this thought may also change this environment.

The philosophers proceeded from the ideas free (as it seemed to them) in their expression, from searching of the restless human thought, and from human conscience unwilling to reconcile with the reality. However it was inevitable that a man constructed his ideal world within the strict limits of the surrounding nature, the environment of his life, the biosphere, though he did not understand (and does not understand now) his profound and independent of his will connection with the biosphere.

We find intuitions and constructions in the history of the philosophical thought existing already for many hundred years

B. C. that may be tied up with scientific empirical deductions; if we transfer these thoughts (intuitions) into the realm of actual scientific facts of our time, their roots are lost in the past. Some ancient (of many centuries ago) Indian philosophical trends may be interpreted as such intuitions, if one compares these trends with the achievements of the science of the 20th century[2].

Approximately simultaneously with the Indian thought, but partly later, similar ideas existed in another, smaller cultural region, for much time isolated from the Indian thought—in the region of the Hellenic civilization in the Mediterranean. One can find some germs of these ideas in the times remote from ours by two and a half thousand years. In the political and social thought, the significance of science and scientists for the control of city-states was evident in the Hellenic thought, and distinctly revealed itself in the concept of state elaborated by Plato (427-347).

Apparently, one may not deny (although the fragmentaiy state of the sources that have reached us does not permit one to

2 The oriental and most of all the Indian philosophy, with its new creative work (caused by the introduction of the Western science into the Indian cultural domain), is of much greater interest for the life sciences than the Western philosophy deeply impregnated, even in its materialistic parts, with remote echoes of the Judaic—Christian religious search.

assert it with confidence) that through Aristotle (384-322) these ideas have been accepted in the Hellenic epoch of Alexander the Great (356-323) when after the destruction of the Persian kingdom, a close exchange of ideas and information between the Hellenic and Indian civilization took place for several hundred years. At the same time, the communication was established between those two centers and with the Chaldean scientific thought that had existed for several thousand years before than both the Hellenic and Indian thoughts. The history of scientific work and thought of that important epoch is only beginning to be elucidated.

We have a better knowledge of the Hellenic political and social ideas. We can closely trace their historical influence in the process of the development of a new science and civilization of the European West that had replaced the theocratic ideological structure of the Middle Ages. Actually and distinctly we see their growth only in the 16-17th centuries, in the concepts and constructions by F. Bacon (1561-1626), who intelligibly advanced the idea of man's supremacy over the nature as the goal of the new science.

In the 18th century, in 1780, G. Buffon placed the manifestation of man's control over nature into *the context of the history of the planet* not only as an idea but as an observable natural phenomenon. Buffon proceeded from the hypothetical reconstructions of the past of our planet tied up with the philosophical intuition and theory and not with the precisely observed facts. But he sought for such facts. His ideas covered the area of the philosophical and political thought. There can be no doubt that they had influenced the course of the scientific thought. The geologists of the late 18th-early 19th centuries often proceeded from his ideas in their current research.

17. The scientific schemes by Schuchert and Pavlov as well as those of all the research work that had (to a great degree involuntary) preceded them are essentially distinct from these philosophical constructions. However, there is no doubt, and it can be historically shown, that these constructions had influenced the development of geological thought, but they could not provide it with a firm foundation.

From Schuchert and Pavlov's generalizations one may see that the main influence of the human thought as a geological factor is revealed in its scientific manifestation which is a decisive factor in organizing the technological work of the humanity, altering the biosphere.

Both geologists were able to make their generalization first of all because by that time man had settled all over the planet. Except man, no other organism (besides microbes and, perhaps, some herbs) has succeeded settling over such great areas of the planet. And man did it in another way, as compared to microbes and herbs. He changed the biosphere by his scientific thought and by his labor, he adjusted it to himself, and created conditions for the display of his biogeochemical power of reproduction. Such settlement over the planet became evident by the early 20th century, and by the first quarter of this century it became an actual fact, strengthening from year to year before our eyes.

The mode-of-life conditions changed abruptly, due to a new ideology; a sharp alteration of the official state goals, and the growth of know-how have occurred by that time. All this made the settlement of the biosphere possible.

As it was duly noted by J. Ortega-y-Gasset[3], the second half of the 19th century (in Europe and in the world) was a historical period when the importance of the life interests of the people began to occupy, actually and ideologically, the first place in the mind of masses and in the mind of state leaders, this for the first time in the universal history. This state of things first of all manifested itself in the everyday life. It was for the first time that a new ideology became based on the consciousness of the people's masses that had advanced as a social force at the historical scene. This ideology begins involving all humanity and peoples, without any exception at an increasing pace.

Actually, it would only tell upon the history with the course of time.

The social-political ideological overturn in its main part manifested itself in the 20th century owing to the scientific work,

3 J. Ortega-y-Gasset, *The Revolt of the Masses*, London, 1932, p. 19, pass.

scientific definition and elucidation of the social tasks of the humanity and the forms of its organization.

18. In the multimillennial historical tragedy, full of blood, pain, crime, misery, and hard life conditions, that is called by us the universal history, the problem of a better life arrangement and the optimal ways to achieve it, emerged repeatedly. Man was never reconciled with his life conditions.

The results of this search varied, and, in the history of humanity, we see many philosophical, religious, artistic, and scientific attempts in this direction, many of them vanished without leaving a trace. For millenia, in all parts of the Earth where the human society existed, this search has been and is being carried out.

The universal history of the humanity has been seen and represented by many people, and in some places and at times, by most people, as a vale of misery, evil, murder, hunger, and suffering. This was an insoluble task from the human viewpoint based on the domination of Reason and Good. In general, the innumerable philosophical and religious attempts after many thousand years did not give a common explanation.

In the end, all the solutions obtained by these attempts have transferred (and do transfer now) the question into another context: from the context of the reality into the context of the ideal notions. Found are the innumerable and various in their form religious-philosophical solutions actually tied up with the notion of the personal immortality (in the direct significance of the word, with some shades of meaning) or of the future resurrection in new conditions, without any evil, suffering, and plague, or where all this will be distributed justly. The most deep is the notion of the metempsychosis solving the question not from the viewpoint o a human being but in the aspect of all the living substance. This notion was put forward several thousand years ago, but it is still alive and bright for many hundred million people. And, perhaps, it nowhere contradicts the current scientific ideas. The course of scientific thought nowhere comes to conflict with the inferences from this notion.

All these notions, far as they are sometimes from the precise scientific knowledge, present a mighty social factor through millenia. This factor is strongly reflected by the process of transformation of the biosphere into the noosphere, but is also far from being a decisive one or to a some degree standing out among the other factors of the emergence of the noosphere. In this aspect, during tens of millenia, the said notions played sometimes the most important part, sometimes were lost among other factors, became second-plan agents, could be left without attention.

19. For there is also another way by which the same process of the world history is reflected in the nature that surrounds the man. One may and ought to approach this process purely scientifically, letting aside all the notions not ensuing from the scientific facts.

The archaeologists, geologists, and biologists come now nearer to such study of the universal history of the humanity. They let aside all the millenial notions of philosophy and religion, do not take them into account, create a new scientific understanding of the historical process of the human life. The geologists have deepened into the history of our planet in the post-PIiocene time, in the glacial epoch, and collected a large amount of scientific facts displaying the reflection of the life of human societies (in the end, of the civilized mankind) upon the geological process taking place over our planet, essentially in the biosphere. Without evaluating these facts as evil or good, not touching their ethical or philosophical aspects, the scientific work, the scientific thought fix a new fact of the major geological importance in the history of the planet. This fact consists in the display of the new *psychozoic* or *anthropogenic geological* era which is being created by the historical process. Palaeontologically, this era is essentially defined by the advent of man.

In this scientific generalization, all the innumerable geological, philosophic, or religious ideas on the importance of man and his history do not play any considerable part. They may be easily left apart. Science is not bound to take them into consideration.

20. Taking up an analysis of this scientific generalization, we may note that the duration of its object can be estimated to comprise about millions of years, while the historical development of the human societies covers several decamiriades (several

hundred years) of this duration.

First of all, one must emphasize several premises defined by this generalization.

The first premise is the *unity and equality (essentially in principle) of all the people*, of all the races. Biologically this is expressed in the manifestation (through the geological process) of all the people as *an integrity* in relation to the rest of the planet's living population.

And this is so despite of the eventuality, and even probability, of the emergence of various human races from different species of the genus *Homo.* This difference hardly goes deeper, to the different animal ancestors of the genus *Homo.* But such a possibility has not yet been denied. Generally speaking, such unity with relation to all other forms of life is retained through all universal history, though in some times and at some places, in special particular cases, it was absent or almost absent. We meet such cases even today, but the general spontaneous process does not alter.

In this connection, one may say that this process was the first phenomenon wherein the geological importance of the humanity became clearly manifested. Perhaps even several hundred years ago when man mastered fire and began making the first tools he laid the foundation of his advantage over the higher animals in the struggle, which took an enormous place in his history and finally had been finished (theoretically speaking) several hundred years ago, with the discovery of the fire-arms. In the 20th century, man ought already to use special efforts not to destroy all the large mammalians and reptiles whom he is to conserve, proceeding from some or other considerations. But during the many earlier tens of million years, nearer to the moment of the emergence of man, he was a new force over our planet that had taken an important place among the previously existed agents, which had annihilated the species of the big animals. It is highly probable that man in his beginning had not been too dissimilar to other gregarious predators.

21. From the geological point of view, far more important was another shift, which lasted tens of thousands years ago: the domestication of the gregarious animals and the working out of

the cultural races of plants. By this way, man began changing his environment and creating a new, never pre-existing at the planet, living nature for himself. The major significance of that had manifested itself also in another fact: man had defeated hunger by a conscious, creative (and not more than to a slight degree known to animals) guarantee and thus found a possibility to reproduce himself unlimitedly.

Owing to this shift, by that time, probably earlier than ten or twenty thousand years ago, a possibility first emerged to form great settlements (towns and villages), and therefore the state structures clearly and essentially distinct from the special kin types of sociality. The idea of the unity of mankind had really, though evidently in an unconscious way, obtained here still greater possibilities for its development.

Due to the discovery of fire, man was able to survive the glacial period, those enormous changes and oscillations of the climate and biosphere conditions which now first are scientifically demonstrated before us in the form of the alternation of the so called interglacial epochs. There had been at least three of them in the Northern hemisphere. Man survived them although some other large mammals disappeared from the Earth. Perhaps man was instrumental in it.

The glacial period is not yet finished. It is still lasting. We are living in an interglacial epoch. The getting warmer still lasts. Man is so well adjusted to these conditions that he does not note the glacial period. The Scandinavian glacier has melted away where are now St. Petersburg and Moscow; this happened only a few thousand years ago, when man already possessed domestic animals and agriculture[4].

Hundreds of thousands generations have passed in the history of the mankind during the glacial period.

But now one may hardly doubt that man (probably not of the genus *Homo*) had already existed much earlier, at least in the upper Pliocene, that is, several million years ago. The Piltdown

[4] Now, the time of the recent glaciation is defined by radiocarborn dating to be about 18-20 thousand years. The glacier did not reach Moscow, it stopped at the Valdai Highland. In the vicinity of Leningrad the glacial cover has melted about 10—12 thousand years ago.—Edit, note

man from the Southern England in the late Pliocene, morphologically different from the modern man, already possessed stone tools and (evidently not conserved) wooden tools, perhaps also bone tools. His brain apparatus had been as perfect as that of the modem man[5]. Sinanthropus from the Northern China, having lived apparently in the early post-Pliocene in the area not reached by the glacier, knew the use of fire and possessed tools[6].

Perhaps right is A. P. Pavlov who admitted that the glacial period, the first ice formation in the Northern hemisphere, began in the late Pliocene and that in this time, under the conditions close to the severe glacial ones, a new organism emerged in the biosphere whose central nervous system was exceptionally developed and led finally to the creation of reason, and now to the transition *of the biosphere into the noosphere.*

All the morphologically different types of man, his various genera and species, seem to have communicated with one another, to have been primordially different from the bulk of the living matter, to have had creative activities sharply distinct from those of the surrounding life; and to have been able to intermix. This was the way by which *the unity of the mankind had been created.* It seems that Osborn was right[7] in his opinion that at the interface of the Pliocene and post-Pliocene, man, still not having permanent settlements, was very mobile, moved from place to place, recognized and revealed his sharp individuality, and thus urged for the independence from the environment.

22. Actually this *unity* of man, his *distinction from all* living, this new form of *the power of the living organism* over the biosphere, his greater *independence from its conditions* (as compared with any other organisms) are the main factors which finally had revealed itself in the geological process of the noosphere formation. During numerous generations, the unity of human soci

[5] The skull from the Piltdown cave, reconstructed from its remains by Charles Dawson in 1912, was actually falsified either by Dawson himself or by some other thoughtless anthropologist. This is a skull of a modem man with the jaws af an anthropoid (F. C. Howell, *Early Man,* N. Y., 1965, pp. 24—25).—Edit, note

[6] Sinanthropus lived 350 400 thousand years ago, in the Middle Pleistocene, which is somewhat later, than V.I. Vernadsky suggested. However, his consideration on the existence of the genus *Homo* “several million years ago” proved to be valid.—Edit, note

[7] *H. F. Osborn. The Age of Mammals in Europe, Asia, and North America, N. Y., 1910.*

eties, their communication and power (their trend to exert power over the surrounding nature) were being revealed spontaneously, before they became evident and were recognized ideologically.

Certainly this was not a conscious phenomenon; the unity of the mankind was being elaborated in struggle and conflicts. There had been mutual extermination of people, sometimes cannibalism and people's hunting on another people. But as a general rule, these three factual manifestations of the future ideas of the unity of man, of his sharp distinction from all living, his urge to master the surrounding nature pass through all history of the mankind, at least through past tens of thousand years. They had prepared the new modem striving to realize them ideologically, as a basis for human life.

This is no more than for the past ten thousand years that we may trace, scientifically and exactly, the real existence of these three factual manifestations of the future ideas of the unity of man. Moreover, in the written literary texts one cannot go further than four thousand years, since the written signs had emerged not long before that time, and the letter alphabet has hardly emerged earlier than three thousand years before our time. As to the real echoes of the ideological constructions, we may hardly expect them in the most ancient monuments earlier than one thousand years before the idiographic letters. Therefore, the retained tradition hardly leads us deeper than six thousand years before present, even if we take into account the now unusual possibility of the oral transmission (from generation to generation) of the ideological constructions elaborated by the peculiar civilizations of those times. The recent archaeological discoveries reveal before us the unexpected fact that the civilized life of our times, the usual for our everyday conditions of the civilized city life, the peaceful exchange of goods, the life technology are the achievements of the ancient world which had been forgotten and never admitted by us, but now, after millenia, found again. These achievements permit us to think that the complex city everyday life existed long before our time, perhaps millenia (six thousand years) ago. By some complicated way, during the millenia, all these achievements have penetrated into all continents, probably not excluding the New World (at this or that period). From the human viewpoint, the New World is not a new one, and by the late 15th-early 16th century, when it became discovered by the Western European civilization, the culture, even the scientific culture, of its states was not lower (indeed, in some relations higher) than the scientific knowledge of the West-Europeans. The American aboriginal civilization only collapsed because the Indians did not know military technology and fire-arms which became usual in the everyday life of West- Europeans several decades before the discovery of America.

Revealed is the picture of the multimillenial history of the material interaction of the civilizations and separate historical centers throughout Eurasia and partly Africa, from the Atlantic Ocean to the Pacific and Indian oceans. In different periods, with interruptions for sometimes several hundred years, this interaction took place also across the oceans. It is highly characteristic that the new cultural centers had been situated at few places. The most ancient are: the Chaldean region as described by Breasted, the Nile valley, Egypt; and the pre-Aryan Northern India. All of them mutually contacted through millenia. A little later (so far not earlier than three millenia before our time) the Northern China center emerged. But here, the [modem] scientific investigations began only three or four years ago and have been stopped by the savage Japanese invasion. Here, some unexpected findings are possible. Perhaps, temporary centers existed at the Pacific coast (in Korea or China) and the coast of the Indian ocean, in Annam. The role of these centers is completely obscure; in this relation, great discoveries are possible.

23. Approximately two and a half thousand years ago, “simultaneously” (with an accuracy of several hundred years) a deep movement of religious, artistic, and philosophical thought took place in various cultural centers: in Iran, China, Aryan India, in the Hellenic Mediterranean (in what is now Italy). The great creators of religious systems emerged: Zoroaster, Pythagoras, Confucius, Buddha, Lao-tse, Mahavira. Their influence embraced millions of people and still lasts.

It was for the first time that the idea of the unity of all the mankind, the idea of human brotherhood transcended the limits of separate personalities approaching it in their intuitions or inspirations. Now this idea became the motor of everyday and social life of the masses; became the purpose of the state units. Since then, this idea did not leave the historical field of the humanity, nor did it come nearer to its realization. Slowly, with many-hundred-year stops, the conditions are being created that enable its putting into life and realization.

It is important and very peculiar that these ideas became introduced into the frame of the real everyday phenomena that emerged in the everyday life unconsciously, without man's will. In these ideas, revealed is the influence of the personality: owing to that influence, the idea can manifest itself in the surrounding biosphere and show itself in it spontaneously.

Earlier, this idea had revealed itself in the poetically inspired creativity that had generated religion, philosophy, and science. All of them are its social expression. Perhaps, the leading religious ideas preceded the philosophical intuitions and generalizations by many hundred years, or even by many thousand years.

The biosphere of the 20th century is being transformed into the noosphere created by the science growth as well as by the growth of the humanity's social life. Later, in the further discussion, I shall return to the analysis of the noosphere. But now I must emphasize the inseparable connection existing between the creation of the noosphere and the growth of scientific thought, that is the first necessary premise for this creation. Such is the condition necessary for the emergence of the noosphere.

24. And it is just in our times, since the beginning of the 20th century, that an exceptional phenomenon in the development of scientific thought is observed. The rate of the development becomes altogether unusual, unseen for during many hundreds of years. Eleven years ago, I compared this development with an explosion—the *explosion of scientific creativity*[8]- And now I cannot but assure this, still more clearly and definitely.

In the 20th century, in the course of scientific knowledge and scientific creation in the history of the mankind, we go through the times which may be equalled in significance only with the phenomena of the very remote past of the mankind.

[8] V. 1. Vernadsky, *Mysli o sovremennom znachenii istorii znanii.* Doklad, pro- chitannyi na Pervom zasedanii Komissii po istorii znanij 14.X.1926, Trudy Komissii po istorii znanij, t. 1, L., 1927, p. 6

Regrettably, the condition of the history of scientific knowledge does not permit us now to make, clearly and definitely, the main logical inferences from the above empirical thesis. We can only assert it as a fact and express under a geological aspect.

The history of the scientific knowledge is the history of the creation of a new main geological factor in the biosphere. This factor is the organized state of the biosphere revealing itself spontaneously during the past several millenia. This state is not an accidental one, but something regular, just as regular is the palaeontological process in the course of time.

The history of the scientific knowledge still remains unwritten. It was as much as we begin to identify (with much pain and great gaps) some facts in it, which were forgotten or consciously rejected by the humanity. Thus we begin to seek for the major empirical generalizations that characterize the history of scientific knowledge.

We cannot still *understand* scientifically this phenomenon that has a great, even enormous scientific and social importance. To *understand* scientifically is to establish the place of the phenomenon within the framework of cosmos as the scientific reality. Now *we* must simultaneously *try to understand it scientifically* and at the same time, use this study for fixing the major landmarks in the *history of the scientific knowledge*—one of the vitally most important scientific disciplines of the humanity.

We now go through a radical breaking of the scientific world outlook that takes place within the life of the now living generations. We experience the creation of vast new areas of knowledge, which enlarges the realm of the science of the late past century. We experience radical changes of research methods with relation both to the space and the time of this cosmos. These changes proceed at a rate which would be in vain searched for in the conserved annals and chronicles of the world science. At an increasing rate, new methods of scientific work and new knowledge areas become generated, as well as new sciences which uncover millions of scientific facts and millions of scientific phenomena whose existence remained unsuspected even yesterday. For an individual scientist, to follow the course of scientific knowledge is a difficult and never completely solved task, to a degree never thought of previously.

Science becomes rebuilt before our eyes.

But more than that, we seem to uncover, with remarkable clearness, an incessantly increasing influence of science upon our life, upon the living and nonliving (inert) nature that surrounds us. The science and the scientific thought that creates it reveal in this *growth of the 20th century science, in this social phenomenon* of the history of mankind that we go through, something new and specific to science, its planetary, alien to us, feature. In it, the science appears before us in a new light.

We may study this phenomenon lived through by us (that is, study it scientifically) from two different viewpoints. On the one hand, it is one of the main phenomena in the history of the scientific thought; on the other hand, it is a manifestation of the structure of the biosphere that reveals to us new major features of its organized state. The close and inseparable ties between these phenomena never stood before the mankind with such clarity.

We live in the epoch when this side of the course of scientific thought becomes manifested before us unusually clear: the course of the history of the scientific thought becomes for us a natural process of the history of biosphere.

The historical process as the manifestation of the world history of the mankind is revealed before us in its one but cardinal consequence, as the natural phenomenon having essential geological significance.

The history of the scientific thought never took into consideration this fact, which is its main feature inseparable from it.

25. Up to this time, the history of the mankind and its spiritual manifestations is studied as a self-sufficient phenomenon, freely and irregularly displayed over the Earth surface, in the environment that surrounds the Earth, as something strange to it. The social forces that manifest themselves through the history are thought of as something to a considerable degree free from the environment wherein the history of mankind involves[9].

Although there exist many different attempts to connect

[1] Here, V. I. Vernadsky seems to be wrong. The "independence" of the social development of the mankind from the changes of environment was argued by F. Engels in his *Dialectics of Nature* and was neglected by the majority of scientists.—Edit, note

the spiritual manifestation of the mankind (and the history of the mankind as a whole) with their environment, it is always lost out of sight that this environment, biosphere first of all, has a very definite structure that determines *all that takes place in it* (without any exception). This structure cannot be broken radically by the process inherent in it, and has (like all natural phenomena) regular changes of its own in space and time.

The scientific creativity explosion occurs and partly, to a certain degree, creates the transition of the biosphere into the noosphere. But, besides that, man himself in both his individual and social manifestations is most closely tied up to the biosphere in a regular and material power relation. This tie never ceases when man exists and has no essential distinction from other biosphere phenomena.

26. Now let us bring together these empirical generalizations.

(1) Man, as he is observed in nature, is (like all living matter) a definite *function of the biosphere,* in its definite space and time.

(2) Man in all his manifestations is a definite regular part of the biosphere structure.

(3) An "explosion" of scientific thought in the 20th century *is prepared by the entire history of the biosphere* and has the deepest roots in its structure. It cannot cease and reverse. It only can become more slow in its rate. The noosphere, that is, the biosphere overworked by scientific thought, prepared by the 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.* The processes prepared through many billions of years, cannot be transient, cannot cease. It follows that the biosphere will transform (in one way or another, sooner or later) into the noosphere, that is, in the history of the peoples populating it, the events will happen necessary for this transformation, and not contradicting it.

The civilization of the "cultural humanity" (in the degree to which this civilization is a form of the organization of a new geological force created in the biosphere) *cannot disappear or cease to exist,* for it is a great natural phenomenon corresponding to the organized state of the biosphere. This state emerged historically, or more right to say, geologically. When this civilization forms the noosphere, it becomes connected to this Earth's envelope by all its roots, which never happened in the previous history of the mankind to a somewhat comparable degree.

27. All the past historical experience of the mankind and the events of the present-day moment, seem to contradict this.

Before proceeding further, I cannot but dwell upon this problem, although in short. It seems to me that the creation (that had begun) of the noosphere, produced by the human thought and labor, changes all the situation of the history of the mankind and does not permit to simply compare the past to the present, as it had been permissible earlier.

Everybody knows the interruptions (long-term, but not only so) in the growth of the scientific thought. But one knows also the cases when scientific achievements became lost and vanished. Sometimes, we see a clearly expressed regression embracing great areas and physically exterminating whole civilizations without any inherent to them and inevitable cause for this destruction. The processes tied up with the demolition of the Roman-Greek civilization hampered the scientific work of the mankind for many hundreds of years, and much of the achieved earlier became lost for long, partly for ever. The same fate overtook the ancient civilizations of India and Far East.

Thence one may well realize seeming unavoidable fear and misgiving before the violent crush of this kind of our time. These misgivings seized the wide groups of thinking people in our time, after the World War (1913-1918), one of the greatest manifestations of the barbarism of the mankind. After the peace has been established, the state forces, as we now clearly see, did not rise equal to the occasion. Now we evidence the results of the unsteady state of the past 20 years tied up with a deep moral crisis—the consequence of the world massacre, a meaningless death of more than ten million people over four years, and of the innumerable losses of the labor of the people. Now, twenty years after the end of the war, we stand before the danger of a new war, still more barbaric and still more meaningless. Now, both factually and even ideologically, the war is waged by means of destruction not of its armed participants alone but also of the peaceful population, including the old men, old women, and children. The facts that were moving away to the past, as something speculative and morally unacceptable, now became a cruel reality.

28. A radical reevaluation of the values took place as a result of the war of 1914-1918, which led to a collapse of the most mighty states with century-old traditions, the states least democratic in their long-term ideals, least free, and representing the base of the old traditions in Europe. These states were based upon an idea of the "equality" of all men expressed within the specific framework of the Christian religions. This idea was the foundation of the Christian ethics. Although the reality never answered this main principle of Christianity (still more of Islam), but it was enunciated in all Christian countries and was (according to the intention) the basis of the state ethics. The reality was entirely and completely different, and for hundreds of years, the Christian states of the white race led practically altogether colonial policy, while paying lip-service to equality. They ruthlessly oppressed, exterminated, and exploited the peoples and states of the non-white races. The war of 1914-1918 stirred up all the world and revealed, before all, a sharp contradiction between the words and the deeds, rose the force and significance of the non-white races.

This did not touch the moral significance of Islam and Buddhism, for they (the real politics of the states that confessed them) lacked the contradiction inherent to the Christian states. In the state life, these religions adhered to the equality of all people of the same faith.

The moral results of the war 1914-1918 were enormous and unexpected for its initiators and instigators. The main result is a sharp change in the state ideology that moved away from the Christianity and led to the division of mankind into the hostile, militant, ideologically irreconcilable groups of states.

Such was an unexpected ideological result of the struggle for tolerance. This result wag the annhilation of the state church or its practical feebleness in state. A kind of state faith emerged.

At this base, state ideologies openly founded on *the idea* *of human inequality,* inequality deep and biological, first acquired strength and got force and development. This inequality acquired the form of a specific state religion or philosophy not concealed behind an ideal of a united religion for all the mankind, the ideal of *the equality of all people.* Also within the white race, inequality was enunciated and put into life by the force of the state power. There emerged the peoples-state outcasts. The moral values of Christianity and "civilized" state faded. As a result, we see the evident moral splitting of the mankind into the state communities of different moral.

The war, tied up with the extermination of the inhabitants with the use of all means for it, becomes recognized something justified for states, like it was before the advent of Christianity, when the means of extermination and destroying were negligibly small in comparison with their contemporary strength, which we now represent to be theoretically almost unlimited.

In Germany, where hegemony of the German race and the state equality of rights, in Italy, where advanced is the state legal equality of a Roman citizen of the times of the Roman empire, and in Japan, where a special position of Japan (as a state established by the Son of the Sun) in the humanity is accepted—in all these states, everything is recognized and admissible for the state: *salus reipublicae suprema lex.* Along with this, these states mean that their population, their full-right citizens have no sufficient area for their development and growth.

Against them, the most cruel war as a fact of action is inevitable, for their aggression meets an understandable resistance.

Their state ideology is an ideology of the past. In an astonishing way, without studying the complexity of the surrounding natural processes occurring now, and resaturating the state ideology of the past that contradicts it, essentially slipping over the surface, they openly challenge the scientific generalizations that deny them; they struggle with the wind mills in an efficient way, by state decrees.

As it was during the past millenia, they try to define the scientific truth by state decrees, admitting the state-organized murders to be a moral good favoring the growth of the virtue of the dominating race.

Their ideal is built upon an ideological recognition of the biological inequality of the human races. Their constructions have nothing in common with scientific achievements, since the philosophy that substantiates their state aims distorts (if necessary) these achievements, or casts them away.

29. An unsteady state is being created that may cause enormous disasters. But we are still far away from the downfall of the world civilization of our time. Its foundations are too deep to be shaken by these events that shock the contemporaries.

This was clearly shown already by the experience of the years 1914-1924. Now another 14 years have elapsed, and we distinctly see that science and forces of the humanity in the surrounding nature grow with an irrepressible might.

Nowhere we see any weakening of the scientific movement among the wars, demolition, deaths of people owing to murders and diseases. All these losses become swiftly compensated by the mighty rise of the practically realized scientific achievements and the progress of the organized state of the political power and technology. It even seems that the science grows still more in this rotation of human disaster and finds in itself the means for ceasing the attempts at strengthening the barbarism.

One ought to take into consideration now the circumstances that never existed to such a degree during the human history. What we go through, cannot be durable and firm and cannot stop the observed transition of the biosphere into the noosphere. But, perhaps, we shall have to suffer an attempt at unleashing barbaric wars in a struggle with a clearly non-equal force.

30. The main geological force creating the noosphere is the growth of the scientific knowledge.

As a result of a long discussion concerning the existence of progress and its incessant manifestations in the history of the mankind, one may now assert that it is only in *the history of scientific knowledge that the existence of progress with time is proved.* In no other field of the everyday human life, nor in the state and economic structure, nor in the improvement of human life (of the basic life conditions of all people, of their happiness) do we observe a durable progress, if only with stops but without returns backwards. Neither do we observe any progress in the area of the moral, philosophic, and religious state of human societies. But we clearly see a progress in the course of the growth of scientific knowledge, that is, in the strengthening of the geological force of the civilized man, in the biosphere, in the growth of the noosphere[10].

G. Sarton proved in his book[11] that beginning from the 7th century P. C. *the growth of scientific knowledge was incessant,* if we take 50-year periods and allow for all the mankind and not the Western European civilization alone. And since then, with short halts, the rate of the progress was becoming swifter.

It is curious that this is the same type of the growth curve that one observes in the palaeontological evolution of the zoological living substance, namely in the growth of its central nervous system.

It seems to me that if we take into account the history of the bettering of life technology, this process would become manifested still sharper and clearer. We have no such history yet. In the final chapters of Sarton's book, one can already see its outlines for the 11 th—12th centuries P. C.

Evidently, 50 years, approximately two generations, indicates the average accuracy, with which we now can judge about this phenomenon. It is already about two thousand years that we had exceeded this accuracy.

Regrettably, this scientific empirical generalization is not usually taken into account, while it is of greatest significance. Certainly, it ought to be refined, but the fact itself does not leave any doubts, and further investigations probably will show that it was even more expressed than we think it now.

31. The following phenomena are observed now and make us to think that the fears about the possibility of the collapse of civilization (with reference to the growth and stability of the noosphere) are devoid of substance.

[10] In this paragraph, V. I. Vernadsky contradicts himself.The progress in the sci entific knowledge inevitably results in the progress in many other fields of human life, in particular, in bettering of life conditions for the majority of the mankind. Edit, note

[11] G. Sarton. *Introduction to the History of Science,* Vol. I. Cambridge, 1927, Vol.2. 1931.

Firstly, the history of the mankind never had this now- observed universality. It consists, on the one hand, in the complete occupation of the biosphere by man, on the other hand—in the absence of any isolation of separate remote settlements, owing to the rapidity of communications and movements. The communication may be instantaneous and have ubiquitous resonance. Soon, one shall be able to make visible to all the events taking place thousands kilometers away. Theoretically, one may hasten the communications and transfer of things to any degree, and their rate grows as rapidly as never before.

Secondly, never in the history of mankind, the interests and well-being of everybody (and not of separate persons or groups) were the real state aim. Now, the people's masses acquire the always growing possibility to influence consciousnessly the course of the state and social affairs. For the first time, the struggle against poverty and its consequences (underfeeding) became a real biological-scientific and state-technological problem that already cannot escape attention.

Thirdly, another problem of similar kind arose for the first time: the problem of the conscious regulation of reproduction, life prolongation, struggle with diseases for all the mankind.

It is for the first time that this problem became formulated with respect to penetration of the scientific knowledge into all the mankind.

Never before occurred such a set of actions and ideas common to all the mankind, and it is clear that this movement cannot be stopped. In particular, scientists in the nearest future are to deal with the tasks unprecedented for them of the conscious regulation of the organized state of the noosphere. They cannot avoid these tasks for they are directed to them by the spontaneous growth of the scientific knowledge.

There is one more circumstance which still has not got a clear expression but which became cleared up. This is the international nature of science, its striving for the freedom of thought, and the consciousness of the moral responsibility of scientists for the use of scientific discoveries and scientific work for the destructive purpose that contradicts the idea of noosphere. This trend did not still became formed, but it seems to me that the world scientific social opinion is being quickly taking shape and enlarging in this direction. In the history of philosophy and science, especially in the epoch of Renaissance and in the beginning of the New Times, when Latin was the scientific language independent on countries and nationalities, the real but ininstitutionalized internationale of scientists played an enormous role and had deep roots in the medieval community of a real but nonformal internationale of the philosophers and scientists.

Therefore, the traditions of the internationale of scientists have deep roots. The consciousness of its necessity more and more penetrates into the scientists, and this trend goes in unison with the purpose of the creation of the noosphere. But for this time, the character of scientific internationale must inevitably be distinct from that typical for a series of generations of medieval scientists and concealed in the Islamic and Catholic environment under the guise of orthodoxy. Now the scientists present a real force. The specialists, engineers and theoretical economists, applied chemists, live-stock experts, agronomists, physicians (who even before played the major part) make up the main bulk and all the creative force of the peoples' leaders.

All said above indicates that in our stormy and bloody time, the real situation cannot permit the development and history of the barbarization forces that now seemingly become advanced to an eminent place[12]. All the fears and reasoning of the philistines, representatives of the humanities and philosophy, about the possibility of the fall of civilization are tied up with an underestimation of the force and depth of the geological processes, like the one we now go through, namely, the transition of the biosphere into the noosphere.

I shall return further on to the elucidation of the notion of the noosphere and to the inevitability of its creation, therefore the inevitability of the creation of the new life forms for mankind.

Now several more considerations about the development of the scientific knowledge.

32. To scientifically understand the progress of science that is taking place, one must first of all put the development of

[12] See final remarks of V. I. Vernadsky in his paper *Some Words on the Noosphere*.—Edit, note

the scientific knowledge within the framework of the scientific analysis of reality, and connect this analysis with the present-day progress of science. Just as the life of any separate human personality, the history of mankind may not be severed from its "environment", may not be considered separately from this "environment". In such general form, this assertion does not rise any doubt, no matter how we define "environment" and which admissions we make, proceeding from the philosophical or religious ideas about the existence of other and independent from the environment factors of equal force.

Embracing the nature scientifically, one proceeds from the said main thesis about the causal connection between all the phenomena of the surrounding world. That is, one reduces the phenomena to a single principle. Science does not admit the existence of the factors independent "of the environment", for science proceeds from the admission of the unity of the environment, of the unity of the cosmos.

I do not touch upon here this way of scientific thinking, I am not proving its correctness or necessity. I only ascertain what is at every step shown to be efficient and correct by the contemporary scientific thought which builds our entire life.

Remaining on the ground of scientific search and logically correct reasoning, I have no need to proceed further.

The development of science in the 20th century has led (unwanted for, in a pure empirical way) to a limitation of this century-old rule of scientific work. *Three separate levels of reality* became identified, within which the scientifically established facts are enclosed. These three levels seem to be sharply distinct from one another in relation to their space-time properties. They are interpenetrating but certainly closed and clearly demarcated with reference to the content and the methodology of the phenomena that are studied in them. These levels are: the phenomena of space; the planetary phenomena of the "nature" akin to us; and the microscopic phenomena in which gravitation loses its importance.

Scientifically, the life phenomena are the only ones observed at the two latter levels of the world reality.

The scientific study of reality ought not to take into account other reality concepts admitting the existence (in the scientifically studied reality) of constructions neither observed nor discovered by scientific search. The usual and dominating ideas on the world (on the reality) are overfilled by the religious, philosophical, historically-habitual, and social constructions that often contradict to those accepted by scienceor, sometimes, to the constructions which are taken into account by individual researchers or groups of researches in their scientific work.

The contradiction between these ideas permeates scientific thought; the scientific cognition of reality frequently strikes them. This cognition in necessary cases breaks the constructions alien to it, and this is to be taken into account when it is correct. All other reality concepts (the religious, philosophical, social-state ones) worked out should be remade in the case of their contradiction to a truth found out scientifically. *The primacy of the scientific thought* in its area, that is, in research, exists always. Independently of the fact whether this primacy is recognized or not, the proper inferences from the research are generally obligatory. This does not depend upon our will. In the spiritual life of the humanity, this situation is characteristic of the scientific thought only.

This assertion essentially does not require any proof. It is an empirical *fact* found out on the basis of the observations of the course of the history of the scientific thought.

This becomes essentially clear in such moments as the current one.

33. The science and the scientific work as a whole result not *only* from the studies of individual scientists, their conscious sought for the scientific truth.

As a general rule, the science, the scientific work, and the scientific thought are not a product of a cabinet scholar who is far from life and who is deepening into a scientific problem created by him or chosen by him voluntary and independently of the surrounding world. A medieval West-European monk, who was (though not for a long time) at the head of the science of his time, generally speaking, was not an anchorite of science. Neither a priest of the ancient Egypt or Babel tied up with life by a thousands of ties nor a 18th-century scientist of the Western Europe and Northern America was a recluse. They and the majority of scientists never were such people of another world as it was and is often depicted by the art and everyday opinion. Individual erudites and amateurs of higher society, monks, or hermits might be so detached, but they were completely lost among the general multitude of scientific workers, and their role, though sometimes honorary and necessary, may only be seen and felt under a scrupulous and detailed study of scientific creativity. Not these people are the creators of science.

Science is a creation of life. It takes its material from the surrounding life and gives to it a form of scientific truth. It is the very midst of the life that creates (first of all) this material. This is a spontaneous reflection of human life in the environment of man, *in the noosphere.*[13] *Science is the manifestation of action in the human society as an integral complex of human thought.*

As a general and really existing rule, a scientific construction is not a logically coherent system of knowledge consciously determined by the reason in all its bases. This system is full of incessant changes, corrections, and contradictions. It is very dynamic (like the life itself) and complex in its content; it is essentially a dynamic unsteady equilibrium.

Logically coherent may only be, and sometimes are, the rationalistic or mystic constructions of the philosophical systems, or theological (and mystic) manifestations of religion proceeding from the theses accepted as the truths and logically developed and deepened without any dependence of the facts of the surrounding nature, including the fact of the social milieu of the mankind.

The system of the science taken in its whole is always imperfect from the logical-critical viewpoint. Only a part of this system, though a permanently increasing part, is unquestionable; this is logic, mathematics, and scientific apparatus of the facts. The really existing sciences which are historically manifested in the development of the mankind and in the biosphere are always embraced by the countless (for the contemporaries inseparable, alien to them, and reworked by them in the historical process) philosophical, religious, social, and technological generalizations and achievements, whose processing

[13] This must inevitably lead to some new forms of the state life, for now the obstacles for the free scientific thought are created by state (§ 28), under the simultaneous utmost growth of the importance of the science for the state.

essentially comprises the main *content* of the development of the science history. *Only a part* of science, although, as we see, its ever- increasing part and main content, which is very often missed by the scientists and also often alien to other manifestations of the spiritual life of the mankind—only the mass of scientific facts and logically constructed upon them and correct scientific empirical generalizations are unquestionable (and logically obligatory and indisputable
for all the people and all their concepts, without any exception)[14.] The science as a whole does not have such an obligatority.

34. Thus the science is far from being a logical construction or a truth-searching apparatus. One cannot know a scientific truth by logic (only by life). The *action* is characteristic of the scientific thought. Scientific thought-scientific creativity-scientific knowledge develop in the midst of life and are inseparably tied to it. The very existence of the scientific thought stimulates active manifestations in the life environment. These manifestations are by themselves the distributors of scientific knowledge, but at the same time they create countless forms of revealing of this knowledge and generate a non-exhausting source of the growth of the large-scale and detailed scientific knowledge.

Thus a human personality, even in our times of science organization, is far from being always a creator of scientific ideas and scientific knowledge. A large- or small-scale scientist-inves- tigator, even living solely upon his scientific work, is only *one* of the creators of scientific knowledge. Beside him, separate individuals are advanced from the midst of life who are accidentally (in an everyday way) tied up with scientifically important areas. They are led by the considerations often alien to science but reveal sci- entific facts and scientific generalizations, sometimes very important and even decisive; they may sometimes formulate the hypotheses and theories widely used by science.

Such scientific creativity and scientific search proceeding

[14] I tried to explain the structure of science in my introductory lecture in the University of Moscow read 33 years ago, namely in the academic year 1902/1903, and several times retyped: *Voprosy filosofii ipsikhologii,* kn. 65 (V), Moscow, 1902, pp. 1410-1465; *Sbornik po filosofii estestvoznaniia,* Moscow, 1906, pp.104-157; *Ocherki i rechi,* vol. 2, Petrograd, 1922, pp. 5-40. There is much in it which should be changed now, but the base seems to be right. This book partially is the last result of my thoughts and investigations, whose first contribution had been made in my speech of 1902.

from the actions outside the scientific, consciously organized work of the mankind are an active-scientific manifestation of the life of the thinking human milieu in a given epoch; they are a display of the humanity's scientific milieu. Judging from the mass of the new in this form of scientific thought introduced into the science and from its importance in the historical results, this part of scientific constructions seems to be comparable with the part introduced into science by the scientists consciously working in it. This is displayed by the fact of the conscious organization of scientific work. Without simultaneously existing scientific organization and scientific milieu, this ever-available and spontaneously unconscious form of the scientific work of the mankind vanishes and, to a significant degree, falls into oblivion, how it had repeatedly been in the Mediterranean area of civilization; during long centuries in the christianized Roman Empire; in the Persian, Arab, Berber, German, Slavonic, Celtic communities of the Western Europe in connection with the collapse of the state structures in the 4th— 12th centuries P. C. and later. With the course of time, science loses its achievements and regains them spontaneously.

The history of science and the history of the mankind reveal such events at every step. The flourishing of the Hellenic science left alone and did not use (or used very late, after millenia) such achievements of the everyday Chaldean science as, for example, the algebra of Babel.

35. However, the environment of life influences scientific thought not only by this single way but also by the introduction of scientific discoveries stimulated everywhere by life and alien to the *scientific search of separate individuals,* and by the integration of these individuals into the organized manifestation of scientific research and into the scientific apparatus of this time.

From a scientific viewpoint, the research by itself, by the team and unconscious work[15], by the course of historical time and by the change produced in this course, creates new and important achievements which may be fixed and may result from the

[15] This work is unconscious in the sense that the scientific achievement or life phenomenon creating a scientifically important or necessary fact (or generalization) did not have such *purpose* in the process of the creation or manifestation of this achivement or phenomenon.

progress of an utmost importance, for example, of the voyages round the world, of the discovery of America, of the fall of the Persian Kingdom destroyed by Alexander the Great, and of the Chinese states and Middle-Asian cultural centers wrecked by Tenghiz Khan; of the victory of the Christian churches and religions, of the emergence and religions-political manifestations of Islam; and of other large and small events of the political life.

Not less, often even more mighty were the changes in the economic life, in the agriculture or in certain progressive achievements of the everyday life; for example, the domestication of the camel (dromedary) in the desert and semidesert areas of North Africa[16] or the discovery of printing in the countries of the Rhine basin in Europe[17].

Parallel with these spontaneous phenomena, whose consequences for scientific thought were not taken into consideration when they were created, the scientific thought itself is acting in the biosphere with the force equal or even greater than these phenomena; under the scientific thought one has to understand scientific discoveries of individual thinkers and scientists who (as Copernicus, Linnaeus, Darwin, Pasteur, P. Curie) change the world outlook of the mankind. In these cases, the change of the world outlook was conscious; in other cases, such change occurred unexpectedly for the scientist himself. Such was, before our eyes, the situation with H. Becquerel (1852-1908), who discovered radioactivity in 1896[18]; or with H. Oersted (1777-1851), who showed the existence of electromagnetism[19]; or with Galvani (1737-1798), who discovered electrical current[20].

[1] Ch. A. Julien. *Histoire de I 'Afrique du Nord Tunisie, Maroc, Algerie.* Paris, 1931, p.178. On the significance of this phenomenon see: S. Gsell. *Memoires de I'Acad.de Inter,* 1926, no. 43; B. F. Gantier, *Les Sieges Obscurs Maghseh.* Paris, 1927, p. 181.

*[7] One ought not to forget that book printing was discovered in Korea, several hundred years before Costere and Gutenberg and was widely used in the Chinese state. But Korea and China lacked the factor that gave its vital force to printing; there was no active scientific work in Korea and China of that time.

Henri Becquerel himself thought that he only took uranium for his studies because this element had been studied by his father and grandfather.

[19] Oersted discovered electromagnetism in 1820 (H. C. Oersted. *The Discovery of Eelectromagnetism Made in the Year 1820,* Copenhagen, 1920).

[20] The phenomenon discovered by Galvani was correctly explained by Volta. The explanation of Galvani was wrong but it was he who discovered “galvanism” with innumerable consequences, up to the concept of electricity (see on Galvani: J. L. Alibert, *Eloge historique de Louis Galvani.* Paris).

Maxwell, Lavoisier, Ampere, Faraday, Darwin, Dokuchaev, Mendeleev, and many others displayed great possibilities of science and realized them creatively in the full conscience of their basic significance for life, while their results were unexpected for their contemporaries.[21]

Their thought (for them, it was with a full conscience) influenced the midst of the life, and this influence called to light the application in new forms that became soon reflected in the scientific creation and transformed the everyday life of the mankind, created the new and unwaited for sources of scientific knowledge, which was unexpected and sudden for their contemporaries.

Parallel to these scientists, and also through the midst of the life, through environment, a similar new cycle of scientific problems was created by the inventors. Among them, many were scientifically illiterate, belonging to all social classes and groups; people often having neither relation nor interest for the search of scientific truth[22-]

36. From all the said we may see some eventual results of great scientific importance, namely :

(1) The course of the scientific creation is the force by means of which man changes the lithosphere wherein he lives.

(2) This manifestation of the change of the biosphere is an inevitable phenomenon corresponding to the growth of the scientific thought.

(3) This biospheric change takes place independently of human will, spontaneously; it is a natural and self-sustained process.

(4) Because the environment of life is an organized envelope of the planet, biosphere, the appearance within it (in the course of its geologically protracted existence) of a new factor of its change, that is, of the scientific work of the humanity, is a natural process of the transition of the biosphere into a new phase, a new condition: the noosphere.

(5) At the present historical stage we see this situation

[21] It is interesting that the significance of these results with reference to life became acknowledged several decades after Maxwell, Lavoisier, Faraday, Mendeleev, Ampere.

[22] Richard Arkwright - English mechanican, inventor of a cotton-spinning machine. Zenobe Theophile Gramm - Belgian electrical engineer, one of inventors of dynamo.

more clearly than we saw it before. Here the "law of nature" is revealed to us. The new sciences, biochemistry and biogeochemistry, first enable one to express mathematically some important features of the process.

37. Under this aspect, the acknowledgment by geologists (§ 15) of the appearance of the genus *Homo,* of man, as an indication of a *new era in the history of the planet,* is justified. Before our time, the division of geological history into systems and eras was based upon the geological process embracing all the Earth's crust and not only its biosphere. But even under such division, the sharp change of the forms of the living population of the planet always was the main distinctive feature of the geological systems and eras. As we know now, this change is closely tied up with the great periods of the orogenic, tectonic, volcanic (so to say critical) shifts in the history of the Earth's crust.

In the era of man, or psychozoic era (see § 15), we really have a pattern more contrast than those in the other critical periods of the Earth's crust. We see now radical alteration of all fauna and flora, demolition of an enormous number of species, the emergence of new domesticated races. Beside the creation of a new appearance of the planet through agriculture, there goes (undoubtedly beyond the will and understanding of man) the change in the species of wild organisms adjusting to the new life conditions in the biosphere changed by the culture. In addition to that, one species organisms, *Homo sapiens faber,* have occupied the planet as a whole and became predominant among all the living things. This is something never seen before.

We see now only the beginning of this process and cannot cover by our thought the inevitable future. But it is already clear that *it is not man alone who wins from this.* A. Clark has shown by a series of facts that the insects use all the blessings of the civilization. He succeeded in attracting attention to the possibility of the result that the insects are benefited by the transformation of the biosphere by man greater than the man himself[23]. On another hand, we see the same phenomenon in the area of the diseases of the cultural plants, animals, and men as caused by the world of the

[3] *See: A. Clark, The New Evolution. Zoogenesis. B., 1930*

protists, fungi, and micro-organisms.

38. Although man, *Homo sapiens,* is a surface phenomenon in one of the envelopes of the Earth's crust, namely in the biosphere, a new geological factor—*the reason*—introduced by the appearance of man into the history of the planet is so great as to its consequences and chances given by it that, as it seems to me, one may not object against taking this factor into account for geological division together with the stratigraphic and tectonic factors. The scope of the changes in these cases is comparable.

Moreover, perhaps in this way we may understand scientifically with a great profundity what is the duration of the geological critical period of our planet. In creating the noosphere, we live this period through, and evidently it seems to us under quite another disguise, and we find ourselves in quite another position with respect to it, than it is when we judge about the geological past, when we did not exist on the planet. The geological effects of life first become clear in their historical duration, manifest themselves within the short terms of the historical time.

The "thinking reed"[24], the creator of science in the biosphere, may and must judge here on the geological course of phenomena in another way, for now he first came to understand scientifically his position within the organized state of the planet.

For one may see clearly that with the appearance of man in the history of the planet, a new *mighty geological factor* appeared whose eventual consequences are far beyond those tectonic shifts which have been laid (purely empirically, through an empirical generalization) as a base for the geological distinctions within the framework of the Earth's space-time.

This becomes clear if we take into account that the duration of the geological phenomena exerts another influence, it is altogether different from the duration of the current historical phenomena within which we exist[25]. A hundred of thousand years— a decamiriade—corresponds to a minor part of a geological sec

[24] "The thinking reed"—from a poem by F. Tyutchev.—Edit, note

The historical study of the geological phenomena as related to their nature has developed tentatively. Here, it is to be said, for example, about the duration of the processes of volcanic eruptions, of the laccolites becoming frozen, etc. It should be also noted that the mankind could play a geological part.

ond, when we admit (which may be done with certainty) the duration of three billions years for the scope of our geological observations.

The biogenic effect of the work of the scientific thought can be really seen only by our most distant descendants: this effect will only become clearly and distinctly manifested after hundreds (hardly decades) of decamiriades, like manifests itself the duration of the shifts expressed through the stratigraphic gaps taken as the foundation for our geological eras and systems[26]. They are no instantaneous revolutions: the duration of their intense manifestations (as expressed in the discordant layering, for example, viewed in the scope of historical time) is hundreds or perhaps tens of thousand years, hardly less.

Now we work in science with such accuracy that the strength of the consequences of the geological manifestations (i.e. as reflected in the geological time) when these consequences are overworked by the scientific thought of the biosphere. Now we only observe the manifestations of the scientific thought in the historical time of its geological work. But even here we see clearly that the biosphere has deeply *changed.*

The emergence of reason and its most exact manifestation, the organization of science, is the foremost fact in the history of the planet. Perhaps, this fact exceeds (in relation to the profundity of change) all what we know and that was manifested before in biosphere. This fact has been prepared by a billion years of the evolutionary process and we only face now its action (in beat case) in geological minutes.

39. The appearance within the course of geological time of a rationally thinking and scientifically working being is connected with the process of life evolution, geologically irreversible though with breaks, and proceeding in one and the same direction, towards making the function of the nervous tissue and particularly the *brain* more exact and perfect. This connection is extremely important for the understanding of the planetary meaning of life. The unidirectedness of evolution becomes evident if one confronts the sequence of geological layers, since archaeozoic era with the

[26] The average duration of most of the geological periods is 45—65 million years, that is 450-650 decamiriades.

morphological structures of the life forms which correspond to these layers.

This evolutionary process expressed by the polar vector, i.e. displaying its directed nature, lasted more than two billion years and inevitably led to the emergence of the brain of the *Homo* genus (approximately more than half a million years ago).

Without forming of the brain of a man, the human scientific thought could not evolve in the biosphere, and without scientific thought, there never would be such a geological effect as the *remaking* of the biosphere by the mankind.

The most characteristic feature of this process is the *directedness* (from this viewpoint) of the evolutionary life process in the biosphere. This directedness, as we shall see, is most closely tied up with the radical distinction between the living substance and the inert matter, and corresponds to an altogether particular display (in the biosphere) of the energetic effect of the life history and to a quite particular geometry of the space occupied by the living organisms.

I shall still return to this problem, while here it is to be noted that J. D. Dana in New Haven was the first to have seen (in 1855, without reference to geological consequences, although he was an eminent geologist) the permanent though interrupting direction of the evolutionary process towards the perfection of the brain with the course of the geological time[27].

Just like the great empirical generalization by Ch. Darwin, D. Dana's empirical generalization had been worked out during the many-year expedition round the world aboard the ship *Peacock* (1838-1842) commanded by Wilkes and almost simultaneous with *Beagle*'s expedition (1831-1836); and under the influence of the deliberations and scientific work of the young naturalist in the laboratory of Nature. In both cases, Darwin and Dana worked under conditions when the life of the biosphere during several years was incessantly evident to them in its planetary aspect. This form of work only rarely is met in the history of science.

40. It is very characteristic that the geological action of the

[27] See: J. D. Dana. *Crustacea. With Atlas of Kinety-Six Plates,* vol. 2, Philadelphia, 1855 , p. 1295; "American Journal of Sciences and Arts", N. H., 1856, p.14.

mankind in the rebuilding of the biosphere only became clear after much time of the emergence of the mankind in the biosphere. *Homo,* i.e. the genus "man", appeared many decamiriades ago, while the species *Homo sapiens* probably emerged a half a million years ago.

But still before the emergence of the genus *Homo,* the brain of his ancestors or of the organisms akin to this genus had reached the level which distinguished his mental activity from that of another mammals. *Sinanthropus pekinensis,* a probable ancestor of the genus *Homo* already possessed culture, mastered fire and perhaps also speech[28]. It is evident that the roots of the geological force of the reason can be traced back to the time earlier than the era of *Homo,* to the depth of the ages, for decamiriades before the emergence of the *Homo* genus.

The influence of *Homo sapiens* himself on the Earth's surface only became manifested after many thousands generations after his appearance on the Earth.

It is possible that here we deal with a phenomena which has not influenced the *anatomical structure* of brain as the apparatus of thought; and which result from the prolonged influence of the *social environment.*

The technique of the anatomical brain research is so little sensitive with relation to the mind tied up with the brain that still recently one of the most eminent anatomists, G. E. Smith (1871-1937)[29], noted that he did not see any essential difference between the brain of a man and the brain of an ape.

It is hardly to be interpreted in other way as with reference to the low sensitivity and incompleteness of the methodology. For there may be no doubt that a sharp distinction exists between the biospheric manifestations of the human mind and the ape's mind which are closely tied up with the geological effect and the brain's structure.

It is probable that, in the development of mind, we deal

[28] *Mandibles of Peking Man,* Nature, 1937, vol. 139, no. 3507, pp. 120-121; F. Weidenreich. *The Mandibles of Sinanthropus Pekinensis: a Comparative Study,* Paleontologia Sinica, Series D, 7, Fasc. 3, Nanking and Peking, National Geological Survey.

[29] G. E. Smith. *Human History,* N. Y., 1929.

with the manifestation not of the crude anatomical change of brain displayed in the geological duration by a change of the cranium: but of the subtler change of the brain tied up with the social life in its historical duration.

Then the necessity of the long trains of generations becomes understandable for the scientific knowledge characteristic of *Homo sapiens* exerted its influence upon the work of man changing the surface of the planet. Tens of thousand generations passed after the appearance of man in the biosphere before this influence became notable.

Such more notable influence of man upon the change of the planet's surface may be dated by the time of the discovery of fire and agriculture by man which happened hardly before 80-100 thousand years ago[30]. Since then, when the influence of man upon the surrounding nature began inevitably to be felt, although there remained a big way to science and organized research, many new tens of thousand years elapsed before the emergence of scientific thought and some level of organization tied up with it, for the scientific thought is a social phenomenon rather than the creation of separate eminent minds. As to the scientific thought and organization, the social life conditions must precede them, within which a separate personality would obtain a possibility to move its thought within the social environment. Which is most probable, these first forms of science organization were for a long time ephemeral, and many ages, or rather millenia, passed before these forms became established.

Regrettably, notwithstanding significant successes of anthropology, history, and archaeology, our knowledge in this area still remains very unreliable.

I look upon the further exposition as upon a transient first approximation further on to be altered to a greater degree and made more precise. With all that, unchanged will remain the main inference that the scientific movement of the 20th century is one of the greatest phenomena in all the history of the scientific thought.

Probably, more than 5-6 thousand years ago the first exact

[30] The reports by N. I. Vavilov make us to fix the creation of agriculture in a far more remote time.

inscriptions of scientific facts were made in the connection with the astronomic observations on celestial bodies. The centers of such observations became established in Mesopotamia—the area of one of the most ancient cultures.

Perhaps still earlier mathematics became a distinct knowledge area covering arithmetic, algebra, and geometry.

At the same time, the principles of geometry were elaborated from the demands of agriculture and related to it irrigation; and from the demands (commerce, military and tax demands) of the complex everyday life of the great states, the principles of arithmetic.

To that epoch, the ideas on the order calculation, on the importance of position in the designation of numbers became clear. Implicit in these ideas was the concept of zero, although it became formulated only in the full flourishing of scientific knowledge. The Hellenic science (see § 42) missed this concept, Western Europe got it during the Middle Ages. Centuries before that it was already known in India, Indo-China, and the Inca kingdom: at least in 609 B. C., almost two thousand years before its recognition in the Western Europe[31].

Now the general picture begins elucidating more accurately.

As it is indicated by the archaeological findings, zero and decimal calculation were known about 3000 years B. C. in the pre- Aryan civilization of Mohenjaro in the Indus basin. This civilization was in contact with Mesopotamia. In the Hammurapi epoch (2000 years B.C.), Babylonian algebra reached so high condition that it cannot be explained without admitting the work of the theoretical thought. It is evident that the achievement of such state of knowledge took many centuries, if not millenia[32].

At the same time, everything indicates that 6000-7000 years ago the migrations, that is, the replacement of the people of the then existing social units (and the knowledge tied up with

[31] The independence of the ancient Indian mathematical thought from the ancient Hellenic one is very doubtful. But one must take into consideration that the use of "zero" (alien to Hellenic mathematics) was known for the ancient Indian culture as early as in the 7th century B. C., and perhaps earlier. From this viewpoint one must note that in the 7th century B. C. zero was already known also in Peru (see the works by F. N. Ludendorff).

[32] O. Neugebauer. *Vorlesungen uber Geschichte der antiken mathematischen Wissenschaften.* Erster Band. "Vorgriechische Mathematik", Berlin, 1934.

these migrations— navigation), the mobility of the masses of people were greater than it was observed during the subsequent historical time[33].

Then, the quantity of population could not be very great. The small groups of people or families could migrate quickly.

The domestication of herd animals and the discovery of the techniques of motion through waters perhaps enables one to understand such features of this remote past as the occupation of all continents and the crossing of the Pacific and Atlantic oceans, which was done by one single species *Homo sapiens.* Another explanation is also possible though less probable, that independent centers of formation of the species of a single *Homo* genus existed, namely, of the species *Homo neandertalensis, Homo sapiens* etc., and that these species became mixed during the further course of history.

41. In this time, the biosphere surrounding man had altogether another appearance, alien to our ideas on the biosphere. Major geological changes have been lived through by man during this heroic age of the creation of the *noosphere.* The creation of the cultivated nature (domesticated plants and animals) had just begun, or was to begin by the efforts of a few following generations. Man had gone through the glacial periods (the advent, transgression, and regression of ice covering enormous areas in Eurasia, particularly in its western part, in the Arctic and Antarctic zones; and in North America). At this time span which lasted at least for a million years, climate and all environment were changing more abruptly than nowadays, under the influence of the said processes. The level of the World Ocean (of the hydrosphere) oscillated to a degree not observable now. The subtropical and tropical areas of our southern latitudes and of the northern latitudes of the Southern hemispere went through *pluvial periods* (for example, Sahara had such a period).

Man endured the pluvial periods just as he endured the glacial epoch. The pluvial epochs, being the manifestations of one

[33] In the latter years, the migration theory had been advanced by G. E.Smith in a series of works beginning from 1915 (G. E. Smith. *The Migrations of Early Culture,* no. 9, 1915; comp.: G. E. Smith. *Human History,* no. 9, 1929. See also the work by one of his pupils: W. Perry. *Children of the Sun. A Study in the Early History of Civilization,* London, 1923.)

and the same phenomenon, are completely alien to our ideas, and it is long time since they escaped human memory.

Now we know the manifestations of the last stages of the last glacial period in its vestiges in Greenland and in the northern North America (in almost uninhabited Canada and Alaska) or in the Antarctic area where man is only temporarily present and still did not colonize even its islands.

As it is to be expected from all the said above, we now also find the last stages of the last pluvial period. We see its remainders in the tropical and subtropical countries, in the humid forests of the tropical Africa, particularly in hyiea, and in the forests of South America. The system of the Amazon and the plains of Central Africa give us a concept about the said state of the biosphere. In Eastern China, we may study the reminiscences of the alien to us biosphere of that period, with the help of the historical legends and the excavations.

Man survived the first offensive of the glaciers, the beginning of the glacial period, during the Pliocene. Perhaps it was another socially-living genus of man, and not the *Homo* genus. He also survived the offensive of the humid forests (and marshy spaces that replaced the forests and steppes) of the preceding biosphere state, that is, of the "mammalian kingdom" which lasted for tens of million years. Man arose in the very end of the period when the environment was dominated by this "kingdom".

In this critical period of the biosphere, with an accelerated rate of change of its face when the biosphere transformed into the noosphere, man was to lead cruel struggle for existence. The biosphere was occupied all over with the mammals who covered all its parts suitable for human settlement and providing the man a possibility for reproduction.

Man found an immense number of species which are now for the most part extinct. Among them there were big and small mammals. He seems to have played the leading part in their extermination, owing to his discovery of fire and the bettering of the social structure. The mammals gave him most of his food owing to which he could reproduce himself intensely and occupy greater space. The beginning of the noosphere is tied up with this man's struggle with the mammals over space for habitation.

42. Our knowledge in this area are now changing rapidly, for the ancient cultures are just now beginning to be understood through their material monuments. I mean the ancient cultures that had existed uninterruptedly and continuosly not in Europe alone, but also in the Indian and Chinese conglomerates of the mankind, in the American and African continents.

One may say that the monuments of the Indian past that for four thousand years before present had connected this great cultural center with the Chaldea have just appeared before our eyes. Almost during the same time we begin to penetrate into the past of the Chinese cultures[34] (§ 43). These investigations have shown much unexpected and mainly indicated the connection (at least in India, in its West, in the Indus basin)—with the Chaldea (the Mediterranean center) and the high level of the folklore creative work that had been current there during many centuries (or many a thousand) of the people's creativity.

In several years, our ideas on these subjects will change radically for it is clear that the (being discovered now) ancient civilizations of China and India had existed during thousands of years before they reached the level of culture discovered by the recent findings. And these cultures are evidently not the most ancient in the world.

Against the background of these ancient cultures, in the mutually remote centers (Mediterranean area, Mesopotamia, Northern India, Southern and Middle China, Southern and Central America, perhaps also elsewhere), the geological work of the scientific thought was going spontaneously, i.e., with the force and character of the natural processes in the biosphere.

This work manifested itself in the creation of the main tenets and generalizations of science, of the *theoretical scientific thought,* in the work tied up with the elucidation of theoretical abstract positions of scientific knowledge, such elucidation being the aim of human activities; in the search for scientific truth as

[34] The character of this penetration in its connection with the movement of the scientific thought is well analyzed with relation to the understanding of the foundations of the culture in the works: R. Rolland. *La vie de Ramakrishna.* Paris, 1929; R. Rolland. *La vie de Vivekananda et l'Evangile universe!.,* 1.1—II, Paris, 1930; S. Radhakrishnan. *Indian Philosophy.* T. I—II. London, 1929—
1931. This movement is tied up with the profound religious creativity.

such, side by side with the philosophical and religious cognition of the world that surrounds man (while the philosophical and religious cognition is by millenia more ancient than the scientific one).

With a certain, but hardly too great, inaccuracy one may now calculate the time when such creation of tenets occured (in various places and to all apparence, independently). This was the time of the generation of the Greek science and philosophy in the 7th-6th centuries B. C., of the religious-philosophic and scientific interpretations in India and China in the 8th-7th centuries. Perhaps the further discoveries will change our ideas on the pre- Hellenic science, and its contribution will turn out to be far greater than we consider it now (§ 45). The new works continuously increase the volume of knowledge owned by the humanity before the Hellenic science appeared[35]; these works ascertain the authenticity of the traditions of the Hellenic science and the importance of the ancient Egyptian and ancient Chaldean science for these traditions. The Egyptian science was found by the Greeks in its stagnation period, the Chaldean science—in the period of living creativity. The joint work of the Hellenic and Chaldean scientists more than 2200 years ago still is not taken into account by the historians of science. This joint work was a by-product of the violent destruction of the Persian monarchy by the Macedonian kings (mainly by Alexander) who accepted the Hellenic culture.

The contribution of the Chaldean science to the Hellenic one will probably turn out to be far greater than we believe it nowadays.

Now we discover, all of a sudden, the profundity of the achievements of Chaldean algebra. They reinforced (perhaps through Hipparchos and Diophantes) Hellenic (and our) scientific apparatus only on the expire of several centuries after the self- dependent work of the Chaldean scientists ceased or poured in the main stream of the Hellenic scientific thought (§ 45).

The Chaldeans knew the concept of zero when the Greeks hardly possessed the alphabet (§ 40). But this idea did not at all penetrate into the inquisitive thought of the Greeks. In the Western

[35] See the works by O. Neugebauer.

Europe, this idea went into life during the Middle Ages through the Arabs and Indians; and algebra only attracted attention after another five centuries expired, owing to the works by Diophantes, whose biography is completely unknown to us.

There exists a series of conjectures and guesses about the reason of this state of things. Seemingly, the most probable conjecture is that it is tied up with the incompleteness and oddity of the Greek mathematical literature of the 3rd century B. C.-3rd century P. C., that came to us.

What is important is the fact itself, perhaps only connected with this force majeure (and if so, than this fact is not very essential).

But the corrections hardly will be such that will force us to change the modem notions in their essence.

It is possible that the recognition of the search for scientific understanding of the surrounding world as a necessity, as a particular *aim of life of a thinking personality,* arose independently in the Mediterranean area, India and China. The fate of these rudiments has been very different.

From Hellenic science, the united modern scientific thought of humanity evolved. It went through the stages of stagnation but in the end developed into the *world* science of the 20th century with its universalistic nature. The stagnation periods sometimes achieved the duration of many generations when much of what was known before was lost. The maximum interruptions were as long as 500-1000 years, but the tradition never became broken off as a whole (§ 45).

43. For the area of the Chinese cultures, we cannot still indicate authentic achievements in science which would permit speaking about the appearance of the Eastern Asia scientific thought distinct from the philosophic and religious thought and independent of the Hellenic center of scientific search. But the chronology of the Chinese cultural manifestations is still so little known that one cannot deny such a possibility. We must wait for the results of the historic work now existing in this area.

Essentially it were the results of the state excavations of 1934-1935 that first gave us a clear notion of the history of the ancient China. And in this case the historical tradition was found out to be more trustworthy than it had been thought to be.

This culture is more new than the cultures of Egypt and Chaldea, but in part more ancient than the Hellenic culture. Probably it is an independent center of generation of scientific knowledge. In the nearest years, when China will come out of the terrors of the Japanese invasion, we shall obtain a more clear picture. Now we cannot build such a picture.

44. The elements of the organized scientific thought and a series of information pieces that would permit to construct such a picture have existed since long past, but unconsciously, without a purpose of the cognition of the surrounding world. These elements have been created millenia ago, with the emergence of the great human states and societies. However, for a long time, they lacked daring and audacious thought, revolutionary audacity of a personality. So they did not leave a durable vestige. The belief in the exactness of the scientifically established fact did not arise. Neither arose, on the basis of such belief, the scientific explanation of the nature. No successful attempts were made to expand beyond the existing religious conceptions.

The criterion, which is the organized scientific thought, was obtained as a result of activity of a few persons during their analysis of correctness of logical assertions (by the creation of logic), by the search for the main generalizing ideas and scientifically observed facts, by the creation of mathematics and the apparatus of scientific facts (the base for their natural systematics and empirical generalization of facts).

This could take place only in the case when personality could manifest its will in society, conserve this will free in the environment impregnated with an inevitable routine of thousands generations. Science and scientific organizations became created when personality began to reflect critically on the base of the knowledge surrounding it and to seek for its own criteria of verity.

We may only speak about science, scientific thought, their emergence in the humanity, when *a separate person* began to critically reflect on the exactitude of knowledge and to seek for scientific truth as such, i.e. investigation became an end in itself.

The main point was to establish a *fact* exactly and to check it. Probably these demands emerged from the technical work and the everyday requirements.

The establishment of the exact observations necessary in the everyday life and the astronomical examination of these observations by generations (in connection with the after all illusory religious ideas) are one of the most ancient forms of the scientific work. This form is scientific in its essence but alien to science in its motives.

Beside this more precise fixation of facts, the reflection and generalization evolved having led to *logic and mathematics,* and here the social demands occupied the first place.

But as it has been already indicated in § 40, in *mathematics* these reflections led to the creation of the numbers of the decimal system, of the first (algebraic) "symbols", about 4000-2000 years ago. Since 16th-17th centuries, the new mathematics (in symbols, in analysis, and in geometry) covered the overall area of the human thought and work and provided its decisive part in the explanation of nature.

Still more profound was the work of the *logical thought.* Its chronology, particularly in the Indian cultures, still remains not investigated. Owing to an incessant work of many generations of thinkers, a mighty movement of the "disciples" (these were many thousand people during many generations) began not less than 3000 years B. C. in various parts of the state units of the Aryan population of India. These people were the newcomers to the area of the ancient pre-Aryan cultures and the "Dravidian" cultural units. The " disciples" were a strong, philosophical and religious movement having laid the foundation of great logical constructions that remain alive up to now. With the prolonged periods of stagnation of the creative thought (these stops were tied up with the historical tragedies), the Indian logical thought had by itself created a harmonious system for centuries before it became elucidated in the environment of the Hellenic civilization. Perhaps, this system influenced Aristotle's logic which down to 18th— 19th centuries remained the exclusive one which dominated our science.

The Indian logical philosophical thought exerted an enormous influence upon the civilizations of the Asian continent in which (sometimes for several generations) new scientific facts and empirical generalizations were being created. This influence spread to Japan, Korea, Tibetian, Chinese and Indo-Chinese states. In the West, it touched the area of the Hellenistic and Islamic cultural centers, in the South and South-East—the Dravidian Ceylon and Malayan state units. In India, the tradition of the *logical thought* never interrupted, and in the 19th century, under the influence of the united West-European modem scientific culture, renewed strongly and profoundly. Both scientific and philosophical creative work went on growing and found a very favourable milieu of the incessant generations got used to intellectual labor.

45. In the Mediterranean area, this search ever growing during the centuries and made by generations of freely thinking personalities, resulted in the Hellenic scientific thought which (having used the many-thousand-year history of Crete, Chaldea, Egypt and state units of the Indian center of culture) advanced the men who initiated the Hellenic science, during one or two generations in the 7th-6th centuries B.C. Our constructions of science are continuously tied up with this beginning.

Perhaps both in Chaldea and Egypt, as everywhere in the history of the mankind, the periods of regression and stagnation occurred. The Greeks met the science of Minor Asia and Egypt in one of such periods.

We cannot yet reconstruct these periods of the flourishing and decline of the pre-Hellenic scientific thought in their history. Scarcely the peaks of the Hellenic science (whose nature still remains insufficiently known to us) have exceeded in their strength the phenomena observed in the coastal area of Minor Asia (Miletes), Southern Italy, and Hellas, in the 4th-3rd centuries, which was the epoch of the creation of the Hellenic science.

The Hellenic science retained its position almost during a millennium, approximately to the 6th-4th centuries P. C. In these centuries, scientific work weakened and stopped, last came to a decline. It was only partly tied up with the state disintegration, with the political slackening of the Roman Empire. The decline of science was also connected with a profound change in the spiritual mood of the mankind, with its deviation from science, with the decay of creativity in scientific work, with the turn of creative thought to philosophy, religion, and artistic images and forms.

46. But at the same time in the extra-Christian states (in Persia, Arabian caliphate, India, China) an independent scientific work went on preventing the lowering of the level of science. In the end, in the countries of the former western Roman Empire, in the realm of Latin as an international language, and of the Latin culture, and under the influence of this culture, scientific thought revived. Almost a millennium later, in the 13th century, a clear breakpoint was achieved leading in the 16th-17th centuries to the creation of a new philosophy and new science in Western Europe, outside the framework of the state and religious limitations. It became possible owing to the strengthening of the state forms of life, to the growth of technology in connection with the new requirements of life and states, and (after the bloody hecatombs during several generations that had been socially caused by the religious movements) with the weakening and in the end collapse of the moral efficiency of the Christianity, Islam, and Judaism, respectively, in the important and influential groups and classes of the population. At a grave experience, a sudden change in the Western religious consciousness perhaps took place in reality having deepened the religious life of humanity and fixed in a profound crisis a more realistic framework for the manifestation of religious life in the functioning of human societies. Probably the religious creativity now comes out of that crisis. Before the religious consciousness of humanity, a necessity appeared for a new religious synthesis, still seeking for new forms under new life conditions.

In the 20th century, we see a new sudden change in the scientific consciousness of the humanity: I think it is the greatest crisis in this field ever experienced by the humanity, so far as its memory reaches. This crisis is to some degree analogous to the epoch of the creation of the Hellenic science, but it is mightier and wider in its manifestation, more universal. Instead of the state cultural centers dispersed over the coasts of the Black and Mediterranean seas, and other centers (not so closely connected with them, and Hellenic for the most part), instead of tens and hundreds thousand men, now we find all over the planet tens and hundreds million people involved in the process of scientific understanding and therefore of scientific search.

At any rate, we now go through an epoch of a major turning point. The philosophical thought turned out to be powerless to make up for the lost spiritual unity that had bound humanity in a whole. The *spiritual unity* of religion was found out to be an utopia; in fact, the religious faith wanted to create this unity through physical violence, not retreating even before killing organized as bloody wars and mass executions. The religious life broke up into many trends. Neither had the state thought any power to create this vitally necessary unity of the mankind in the form of a single state organization. Now we stand before manifold state organizations ready to mutually destroy one another; we are on the eve of a new massacre.

And just at that time, by the beginning of the 20th century, the *scientific thought,* going through an unseen before explosion of creativity, has manifested itself in a clear and real form as an eventual force for the creation of the unity of the mankind.

It is a force of a geological character prepared by billions of years of the history of life in the biosphere.

This force became evident in its new form for the first time in the history of mankind: on the one hand, in the form of the *logical obligatorily and logical indisputability* of its main achievements; and on the other, in the form of its universality, for it covers all the biosphere, all the humanity, and creates a new stage of biosphere organization. For the first time, the scientific thought manifests itself as a force creating the noosphere, with the character of a spontaneous process.

CHAPTER III

The movement of the scientific thought in the 20th century and its importance in the geological history of the biosphere. The main features of this movement: an outburst of scientific creativity, a change in the understanding of the foundations of reality, the universality of science and its effective social manifestation.

47. What is now going on in the world scientific movement may only be compared in the past of science with the generation of the Greek philosophy and science in the 6th-5th centuries B. C.

Unfortunately we as yet cannot represent clearly that the sum of scientific knowledge which was obtained by the ancient Greeks when scientific thought manifested itself and for the first time received its scientific philosophical structure, independent of religious, cosmogonic, and poetical constructions, when scientific methodology—that is, logic and theoretical mathematics as applied to life— was first created in the Hellenic polis (city) civilization, and when the search for scientific truth became a real end in itself for the life of a person in a social environment.

The circumstances of this greatest (as history has shown) event in the life of the humanity and in the evolution of the biosphere are in many relations enigmatic and are now being elucidated, slowly but more profoundly, by the historiography of the scientific knowledge. One only sees in the first approximation the sum of scientific knowledge of the Hellenic milieu of that time, the achievements of the creators of the Hellenic science of those days, and the heritage obtained by them from the preceding generations of the Hellenic civilization. Now we are slowly beginning to look into this problem. (This is on the one hand.)

And on the other hand, an abrupt change is taking place in the notions concerning what the Hellenes obtained from the science of the preceding great civilizations those of Asia Minor, the Crete, Chaldea (Mesopotamia), ancient Egypt, India.

Unfortunately, only an *insignificant part* of the Hellenic scientific literature came down to us. The greatest thinkers did not leave any trace in the available literature, or we have got but fragmentary data about their research work.

True, the most part of Plato's works has reached us completely and much of Aristotle's scientific work, but out of Aristotle's books, many are lost which are the most important for the history of scientific research. From this viewpoint, one ought to regret especially the loss of the works by the most eminent scholars in whose books the scientific thought and scientific methodology became formulated during the period of the flourishing and synthesis of the Hellenic science. I mean such scholars as Alcmeon (500 B. C.), Leucippes (430 B. C.), Democrites (420-370 B. C.), Hyppocrates of Chios (450-430 B. C.), Philolayous (5th B. C.), and many others, whose only names or insignificant fragments of works have survived.

Perhaps even more regrettable is the loss of the first attempts at historiography of the scientific work and thought, writ ten down in the centuries nearest to the time when this work and thought first became manifested. Partly distorted and incomplete, these attempts came down to us in the form of anonymous elements, sometimes assimilated in other works and changed during many centuries since their first publication. Where as the authentic histories of geometry by Xenocrates (397-314) and of science by Eudemos of Rhodes (circa 320), as well as the historic writings by Theophrastes (372-288) and others became lost in the course of the Hellenic-Roman civilization by the beginning of our chronology, or in the following centuries, almost one thousand years ago.

Essentially the main stock of the Hellenic science, what I name its *scientific apparatus*[1], came to us in insignificant fragments, and moreover (as many centuries elapsed) within the remains of the historic-scientific works by Aristotle and Theophrastes and in the works by the Greek mathematicians. Still it has greatly influenced the Renaissance, i.e., the creation of the West European science in the 15th—17th centuries. To a significant degree, our new science emerged owing to the Hellenic science, proceeding from its achievements, developing the ideas and knowledge contained in the ancient Hellenic works. Though interrupted for centuries as far back as in the times of the Roman Empire, the threads of succession became restored in the 17th century.

48. During the recent years, the progress in science history makes us change our ideas as to the pre-Hellenic heritage upon which the Hellenic science grew, as I indicated in § 42.

The Hellenes themselves have everywhere mentioned the enormous volume of knowledge which they had obtained from Egypt, Chaldea, and the Orient. Now we have to acknowledge this. Before the Hellenes, the science had already existed. The science of the Chaldeans, rooting as far back as many millenia B. C., now starts to be known to us, in fragments that prove indisputably its strength unsuspected by us before (§ 42).

Now it becomes clear that one ought to attach greater importance than before to the numerous indications by ancient

* See: V. I. Vernadsky, *Problems of Biochemistry,* issue 2, Moscow 1939, pp. 9-10.

scholars and writers that, in their creative work, the creators of the Hellenic science and philosophy paid attention to and proceeded from the achievements of scientists and thinkers of Egypt, Chaldea, the Aryan and non-Aryan civilizations of the East.

During several hundreds of years, the Babylonian scientists worked hand by hand with the Hellenic scientists. This was the time (the centuries nearest to our era) of a new heyday of the Babylonian astronomy. Gradually, in the course of several generations, the Babylonian scientists merged into the Hellenic environment. Equally with the Hellenes, the Babylonian scientists suffered from the unfavorable (with respect to science) situation of that time (§ 40).

There is no doubt that, under that communication, the Hellenes applied to their use the knowledge obtained from the Babylonian scientists.

Undoubtedly, the volume of the knowledge acquired and used by the Hellenic science in this way was very great to that time, especially if we take into consideration the many-millenial experience and many-millenial traditions of navigation, technology, agriculture, military and state organization, and everyday life.

For centuries, the Greek science worked also in an immediate contact with the Chaldean and Egyptian science, merged with them. Although at that time the creative work in the Egyptian science possibly died down, which was not true for the Chaldean science (§ 42).

During the epoch of its genesis, the Hellenic science was an immediate continuation of the strong creative thought of the pre-Hellenic science. This fact is ascertained but still not assimilated by the history of science.

The "wonder" of the Hellenic civilization is a historic process, whose results are clear but whose course cannot be exactly traced yet, this process has a firm base in the past. But its result, with relation to its achievements and their rate, turned out to be something unique in time and exclusive in its consequences in the noosphere.

49. The course of the scientific thought of our time, the 20th century, as to its probable result, may lead to even more grandiose consequences; but the process of the development of the

modem science is clearly and evidently distinct from what took place at a little site of the Mediterranean area: the coast of Asia Minor; the islands and peninsulas of the Mediterranean, Aegean, Black, and Azov seas. This was the region where the Hellenic culture penetrated. And scientific creativity was then concentrated mainly in Asia Minor, Mesopotamia, and Southern Italy (the latter being then Greek in its culture and language).

A clear distinction of the scientific movement of the 20th century from the movement that had created the Hellenic science and its research organization consists, firstly, in the *rate* of modern scientific movement and, secondly, in the *area* embraced by it (it spread itself throughout all planet), in the *depth* of its influence, of the ideas about the scientifically accessible reality, and, finally, in the *strength* of the planetary change caused by the science and in the prospects for future which open in the process of this change.

These distinctions are so great that one may foresee the scientific movement at an unprecedented scale in the biosphere.

This movement will justify the geological frontier recently noted by Ch. Schuchert and A. Pavlov in the Earth's history: the frontier tied up with the emergence of the human reason. In the nearest (historic, with respect to its duration) time, the noosphere will become manifested even more evidently.

50. Now we may (and this is an uncommon case in the history of knowledge) mark out the beginning of the current scientific movement so clearly and exactly as it was not possible in any reconstruction of the past.

Perhaps the ancient Hellenes themselves could see this beginning of scientific movement in the 5th-6th centuries, when they wrote their chronicles of the history of science, which are now lost, but were still available to the researches during the first centuries of our era.

So we can not adequately compare our well documented epoch against that critical epoch in the history of the Scientific thought. We may attribute our epoch to the very end of the 19th century, to 1895-1897, when the phenomena tied up with the destructibility of atom became discovered (§ 55).

Our epoch in the history of science manifests itself by an enormous, explosion-like (as to its rate) accumulation of new scientific facts. Beside that, new areas of scientific knowledge and numerous new sciences are being created rapidly, scientific empirical material heaps up. An ever-growing quantity of facts is systematized and taken into consideration. These facts are numbered by millions if not billions. Their systematization grows better and becomes within an easy access of man. It is the process of the so called specialization of science—an *extreme* simplifying in the possibility to operate with the billions of the facts of scientific apparatus. I call "scientific apparatus" a set of natural bodies or real 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. It has been systematized in accordance with the centennial and ever deepening research work with definitely formulated tasks. In every generation, the scientific apparatus is revised critically and precisely. The scientific apparatus consisting of billions of billions ever-growing facts gradually and continuously covered by empirical generalizations, scientific theories, and hypotheses, is the foundation and main force, main instrument of the growth of the modem scientific thought. It is a never seen before creation of new science.

In our country, one often negatively looks at specialization. But in reality, specialization as taken with reference to a separate individual utterly strengthens the realm of its knowledge, and enlarges the area of science accessible to it.

This is because the growth of the scientific knowledge in the 20th century rapidly eliminates the interfaces between separate sciences. To an ever increasing degree, we specialize in accordance with the *problems* and not with the sciences. This permits us, on the one hand, to penetrate deeply in the studied phenomenon, and on the other hand, to embrace it from all the viewpoints.

51. But an even more sudden change is now taking place in the main methodology of science. In this area, the consequences of the newly uncovered areas of scientific facts called to life a simultaneous change in the very foundations of our scientific knowledge, of our understanding of the surrounding world: the foundations partly remained untouched during the millenia, and partly laid for the first time, fully unexpectedly, and only in our

days.

Such a fully unexpected and new main consequence of the new areas of the scientific facts is the heterogeneity of the Cosmos that became manifested to us, as well as the real and corresponding to it heterogeneity of our cognition answers. Also answering to the heterogeneity of the reality is the heterogeneity of the scientific methodology, of the units and standards with which science deals.

Now we ought to discern three realities: (1) the reality of *human life,* of the natural phenomena of the noosphere and our planet taken as a whole; (2) the microscopic reality of the *atomic phenomena* also covering the microscopic life and the life of the organisms not seen to human eye even through special devices;
(3) the reality of the *outer space* in which the solar system and even the Galaxy are lost and become imperceptible in the area of the noospheric cross-section of the world. This is the area partly covered by the relativity theory and manifests itself to us as a result of its creation. The scientific meaning of the relativity theory is based for us not upon the content of this theory itself but upon the new experimental and observational material tied up with the new discoveries of the stellar astronomy[2].

The theory of relativity is permeated by extrapolations and simplifications of reality, by admissions, whose checking by scientific experience and scientific observation (on the noosphere material) still remains impossible, at least now. Owing to that, it occupies only a negligible place in the current scientific research. The relativity theory is much more interesting for a philosopher than for a naturalist who only takes it into account in the cases when he approaches the cosmic reality. In the biosphere, he may never consider it for its manifestations are not observable scientifically.

It becomes clear now that here (just as in the area of atomic science) the scientific phenomena are being uncovered before us which are now first embraced by the thought of man and which

[2] V. I. Vernadsky. *Time problem in the modern science,* lzvestiya AN, 7 ser. OMEN, 1932, no. 4, pp. 511-541; in French: *Lepromleme du temps dans la science contemporaine. Suite.* Revue generate des sciences pures et appliquees. Paris, vol. 46, no. 7, pp. 208-213; no. 10, pp. 308-312.

essentially belong to the other regions of reality (not to the region where human life takes place and the scientific apparatus is being created).

This is because the region of the human culture and the manifestations of the human thought, the noosphere, lies outside the space realms where it is lost as something infinitely small, and outside the realm where the forces of the atoms, atomic nuclei, and particles constituting them reign, and where the noosphere is not present for it may be regarded as something infinitely great.

Both of these new regions of knowledge, the maximum small space-time and the maximum great space-time, are the new (and essentially fundamental) elements introduced by the scientific thought of the 20th century into the history and thought of the mankind.

To the earlier known area of human life (the noosphere), by which the interests of science had been limited down to this time, now two new and clearly different from it areas are added: the world of cosmic spaces and the world of the atoms and their nuclei. With relation to them, one has perhaps to change radically the main parameters of scientific thought: the constants of physical reality to which we quantitatively compare all the content of science.

We still cannot foresee all resulting consequences with reference to the methodology of research. In general, this complexity has only been empirically established by the science. It was foreseen neither by the science nor by the philosophy, nor by the religious thought. Only in a single aspect of this complexity (and in an insignificant one) can we discern the ways of its generation which hide in the remote past and which first became clear in the late 17th century when Leeuwenhoek discovered the invisible world of the organisms, and in the late 18th century, when W. Herschel discovered the world lying outside our Solar system. But it is only now becoming clear (when scientific theory covered the scientifically established facts) that one dealt here with a completely new approach of our thought to the reality in its atomic and cosmic aspects and not with a mere difference in size.

52. It is probable that we shall understand many new things in the nearest future, but even now one may ascertain that the main principle of every philosophy, the absolute immutability of reason and its

effective unalterability, does not correspond reality. In our scientific work, we actually deal with the imperfection and excessive complexity of the scientific apparatus of *Homo sapiens.* It might be foreseen on the basis of an empirical generalization, on the basis of the evolutionary process. *Homo sapiens* is not the crown of creation, he does not possess a perfect thinking apparatus. He is an intermediate link in a long chain of beings which have the past and undoubtedly will have the future. Our ancestors had a thinking apparatus less perfect than ours, and our descendants will have even a more perfect one.

These difficulties in the understanding of reality which we now pass through do not represent a crisis of science, as it is thought by someone, but a slow and difficult improvement of our main scientific methodology. Now an enormous and earlier unseen work is taking place in this direction.

A striking expression of this work is the sudden and swift change of our idea on *time.* For us, time is not only inseparable from space, but something like another manifestation of space. Time is full of events with the same degree of reality as space is full of matter and energy. Time and space are the two sides of a single phenomenon. We do not study space and time, but the space-time. This is done consciously for the first time in the history of science.

Science also approaches space research in a new and profound way.

First in the early 19th century, N. I. Lobachevski (1793-1856) put forward the question in a scientifically answerable form: whether the space of our Galaxy (Universe) is an Euclidean one, or it is a new kind of space, about which he and, independently, J. Bolyai (1802-1860) proved that it can geometrically exist together with the space of the Euclidean geometiy.

Further on we shall see the significance of Lobachevski's way of research for the analysis of the structure of the biosphere, if we make a logical (and seeming to me necessary) corrective to his discourse.

There is no reason to separate the results of geometry and of all mathematics as a whole, with its numbers and symbols, from other data of natural science. We know that mathematics, historically, has been created from an empiric scientific observation of reality, particularly of its biosphere.

Of course, theoretical constructions have always been more abstract than natural objects, and because of it, have eventually been irrelevant for natural bodies and natural phenomena of the biosphere, even if these constructions have been logically correctly deduced from the empirical knowledge. We see this at every step, for all what is empirically known in science is its theoretically admissible manifestations just so infinite as infinite is the biosphere within which the scientific thought reveals itself.

We know that the geometries of Euclides and Lobachevski are two geometries out of an endless set of the possible ones. This set may be divided into three groups: the geometries of Euclides, Lobachevski, and Riemann. Now a general geometry is being elaborated which would cover all these three types. But in the lifetime of Lobachevski it was not known, and therefore he could pose a question about a single geometry of Cosmos. With an equal right, we may speak of the geometrical heterogeneity of the reality: of the simultaneous manifestation in Cosmos, in the reality, of the matter-energy (mostly material, physical) states of space which make various geometries to differ from one another. Further on we shall see that this problem now becomes manifested through the heterogeneity of the biosphere, in its inert and living natural bodies. I shall return to this later (see section IV, § 128). One ought to observe the processes still unknown to us: the processes of the transition of one of such physical states of space (with some geometrical structure) into the space with another geometrical structure.

53. Parallel with this, a new knowledge has been achieved and the analysis has been deepened in the ancient fields of knowledge that, like mathematics, developed a very perfect *logic.* The logic now is being reconstructed. Its more philosophic part, theory of cognition, is now of rather minor interest for us.

The logic of Aristotle is the logic of *concepts.* While in science we deal with natural bodies and phenomena the concept of which is verbally immovable, in the historical course of the development of scientific knowledge the concepts radically change in their interpretations, reflect very profoundly and sharply the condition of knowledge peculiar to a given generation. Aristotle's logic, even with its latest (the 17th century) changes and supplements, which have given many additions, is too rude a tool and must be reworked through a deeper analysis. I shall return to this later in a separate sketch.

54. Mathematics and logic are nothing more than the main ways of building science. Since the 17th century, the century of the creation of the new West European science and philosophy, a new area of scientific synthesis, and analysis emerged: the *methodology of research.* It is by it that the main content of science (empirically, its scientific apparatus) becomes created, checked, and evaluated. I have already spoken (§ 50) about its enormous (and ever-increasing and radical) meaning in the history of science.

It is strange that methodology of research having great literature and very diverse handbooks, has not been covered by the plilosophical analysis as yet, while many separate methodological disciplines already exist: theory of errors, some areas of the probability theory, mathematical physics, analytical chemistry, historical criticism, diplomacy, etc. It is only owing to these disciplines that the scientific apparatus obtains the strength of the penetration into the unknown which characterizes the 20th century and unveils before science of our days infinite possibilities for the further study of nature.

As it is clear from what had been said before, the methodology of research is not a part of logic, and much less, of the cognition theory.

During the past years, there had been some major change in this area, perhaps of greatest significance. A new and peculiar methodology of the penetration into the unknown, is becoming created. This methodology is justified by success but may not be represented through an image (model). It is, so to say, a new concept answering reality and expressed in the form of a "symbol" created by intuition, i.e., by an unconscious for the researcher himself synchronous cognition of an immense number of facts. One cannot understand these symbols with a logical clarity, but we may apply to them the mathematical analysis and create their theoretical generalizations which will be verifiable against the facts in all their logical consequences.

This way of research and discovery is widely applied, particularly in the *atomic physics*[3], the area of scientific cognition entirely included within the microscopic cross-section of the world.

[3] This term used by Le Roy and others seems to be rather inappropriate, for in analogy with this the area of scientific cognition, not only physics, but also biology or chemistry, become changed. It should be right to conserve the term “atomistics”, including in the phenomenon also its aspect related to the atomic nuclei.

The concepts of the quantity, of the photon, quantum are bright examples of this new (and probably, very mighty) force of scientific penetration and of the enlargement of scientific disciplines which are being created (for example, the new mechanics), and new sections of mathematics emerge proceeding from these disciplines.

Our mathematical and logical apparatus is now radically different from what a scientist had at his disposal 40-50 years ago.

But one sees that it is no more than a beginning. With a difficulty, but irreversibly the new methods of the penetration into the unknown become created: the methods tied up with the search and creation of the new areas in the theoretical physics wherein the visual image of phenomena is obscured or even cannot be built up.

But this new methodology is not only applicable to such new knowledge areas as the physics of atoms. Of course one needs much care in using it. There are many fruitless and erroneous applications of it in the scientific literature. But this is inevitable under the conditions of all our scientific work where we make much excessive and unneeded for job. We act in this case just as the nature works, just as the organized state of the biosphere is being elucidated (§ 3). It is very important that, simultaneously with the new methodology, still greater phenomena are observed. Perhaps it is these phenomena (the creation of *new knowledge areas, new sciences)* that call to life this new methodology.

The rate of its creation and the region covered by these areas are continuously growing during the past forty years.

55. Fourteen years ago, I compared this feature of scientific knowledge with an *explosion,* and this comparison seems to me to express the reality in a correct way.

We may trace the *beginning* of this explosion with an unusual exactness. E. Rutherford was right to indicate[4] that the contemporary development of physics that has turned our world upside down, is on 9/10 due to radioactivity, in the problems advanced by the modem physics.

Of course one may be dubious as to the accuracy of such

[4] E. Rutherford. *Zusammenfassende Vortrage zum Hauptthema:* “Radia activi- tat”: Lord Rutherford of Nelson-Cambridge; *Erinnerungen an die Fruhxeit der Radioactivitat (Reminiscences of Early Days in. Radioactivityj.* Zeitschrift fur Electrochemic und Angewante Physikalische Chemie. 1932. Bd. 38, no. 8a, S. 476.

evaluation, for experiment has approached, in a miraculous way, almost simultaneously to the discovery of three new phenomena, essentially inseparable from the radioactivity. It happened during three years at three different places: (1) in Wurzburg, where the X- rays were studied by W. Roentgen[5]; (2) in Paris, where the radioactivity of uranium was discovered by H. Becquerel in 1896[6]; and (3) in Cambridge where J. J. Thomson discovered the electron in 1897[7]. The *coincidence* of these three discoveries defined an explosion of scientific creativity. But, without the discovery of *the main phenomenon of radioactivity*, the destructibility of atoms, explaining both X-rays and electrons and their origin, without this discovery, we would not have the modem physics.[8]

The discovery of radioactivity (just as the discovery of the X-rays and the electron) may be traced with such a scientific exactness with which it can rarely be done. On March 1, 1896, at a session of the Paris Academy, H. Becquerel made a report on uranium's issuing the rays acting on the photo plate; he considered these rays to be analogous to the X-rays discovered by Roentgen

[5] About the story of Roentgen's discovery which could not be understood in its essence without the discovery of Becquerel and its consequences, see: M. V. Laue. *Ansprache by Eroffnung der Physikertagung in Wurzburg.* Physikalische Zeitschrift. Bd. 34, Leipzig, 1933, S. 889-890; O. Glasser.*Wilhelm Conrad Roentgen und die Geschichte der Roentgenstrahlen.* Berlin, 1931, S. 162; Comp, the new literature tied up with the political measures against Roentgen's freethinking: J. Stark. *Zur Geschichte der Entdeckung der Roentgenstrahlen,* Physikalische Zeitschrift, 1935. Bd. 36; A. F. Ioffe. *Wilhelm Konrad Roentgen,* Uspekhi fizicheskikh nauk, 1924, t. IV, iss. 1, pp. 1-18; M. Wein. *Zur Geschichte der Entdeckung der Roentgenstrahlen.* Physikalische Zeitschrift, 1935, Bd. 36, S. 536; G. Garig. *Yubilej Roentgena* v *"tret'ei imperii",* Arkhiv istorii nauki i tekhniki. M.-L., 1936, iss. VIII, pp. 301-308. Prof. Goodspeed obtained the X-ray inages earlier than Roentgen did, but he did not claim his priority for he missed the discovery, just as many others did before Roentgen.

[6] H. Becquerel, *Comptes rendus hebdomadaires des seances de l'Academie des sciences,* Paris, t. 122, 1896, pp.501-503, 559-564, 688-694, 762-767, 1086-1088.

[7] J. J. Thomson. Cambridge. A work coceming the discovery of electron. (See a bright historical essay on the discovery of electron: Compton. *The Electron, Its Intellectual and Social Significance.* Nature, 1937, v. 39, no. 3510, p.231). Crooks missed the electron which he could observe. O. Richardson was close to the discovery. But it was Thomson who worked in the environment permeated by the idea of radioactivity.

[8] It seems to me that even an admission of probabilistic nature of this coincidence is now scientifically incorrect. Now, we left the time when it was possible. This admission is tied up with the ideas on the *occasional* nature of scientific discoveries. But the science, including physics, is an expression of the organized nature of the noosphere, and the course of the development of science is a scientifically understandable natural process. It can contain nothing "occasional".- if we do not leave the domain of scientific thinking.

several months before that. The first snapshots supplied by W. Roentgen had been shown in the Paris Academy on January 20,
1896, and Becquerel immediately began his experiments proceeding from the admitted connection between X-rays and the fluorescence of the cathode lamp glass. He followed an experimentally right way while his premises had been essentially wrong.

Roentgen's discovery elucidated the existence of the "dark" rays penetrating into the matter and acting on the photo plate. Becquerel immediately applied these new experimental ideas (proceeding from the fluorescence with which he connected them) to the salts of uranium. He discovered new rays and proved them to be connected with the atom of uranium for which he obtained both the X-rays and radiation. During the nearest months, due to the efforts of an enormous army of all world's physicists, the concept of radioactivity became created, and the rapid development of the new world outlook began. This explosion was initiated by the discovery of radioactivity.

Now we know that in the annals of science, there are numerous indications on separate facts, observations, ideas, that correspond to radioactivity.

H. Becquerel himself thought that he had only discovered the radioactivity because he had been prepared for it by all his life and by the life of his ancestors. He said: "The discovery of radioactivity had to be made in the laboratory of the Museum d'Histoire Naturelle in Paris, formerly "Jardin des Plantes"; and if my father were alive in 1896, he would be its author".[9]

In fact, the physical laboratory of the Museum of Natural History in Paris is a completely unique phenomenon in the history of science. Continuously since 1815, i.e. already during 123 years, its directors are the members of the Becquerel family: greatgrandfather H. C. Becquerel (1788-1878), A. E. Becquerel (1820-1891), A. A. Becquerel (1852-1908), J. Becquerel

[9] The story of Becquerel's family is very interesting. Its several generations studied the phosphorescence, the phenomena of fluorescence and electrization. Becquerel himself thought that the radioactivity would be possibly discovered much later if he would not try and study the uranium salts, and this study had been a hereditary affair in his family. But even before his discovery, there had been some approaches to this problem (V. I. Vernadsky. *Zadacha dnia* v *oblasti radiia.* - Izvestiia AN, ser. 6, St.Pb., 1911, no. 11, pp. 61-72.

(1878-1943). In this laboratory, the work is being done continuously during many generations (in each generation, since childhood) tied up with the phenomena whose study had essentially led to the discovery of radioactivity.

H. Becquerel was right; in fact, inevitably this altogether new and not conjectured by anyone phenomenon, radioactivity (destructibility of the atom, limitations of its existence in time) ought to be discovered within the Becquerel family, and soon after the X-rays discovery. For it was in this family alone that the research attention of several generation of physicists had been directed to the phenomena of fluorescence, electricity, light action (photography). Already H. C. Bequerel (a physicist with broad interests, whose experiments were mainly devoted to electricity) in 1839 had systematically studied the phenomena of phosphorescence, together with his son, A. E. Becquerel, and with Biot. Partly in connection with these works, in 1852 Stokes discovered the uranium phosphorescence and called it fluorescence. Since 1859, his discovery became a starting point for numerous later works by A. B. Becquerel, jointly first with his father and then with his son, who in the afterwards discovered the radium emanations of the uranium. Already then, some peculiarities of this phosphorescence became clear that have not been fully explained even today, as it seems to me.[10] By 1896, the Becquerels had incessantly studied uranium more than 40 years.

56. Therefore it is no wonder that in 1896, the uranium salts became the first object of research and had immediately led to the discovery of radioactivity. The enormous experience and acquaintance with these phenomena had been accumulated by three generations of the Becquerel family to the time when Roentgen's X-rays discovered the new gamma radiation also related to the fluorescence phenomena studied by the Bequerels.

I have analyzed this story in some detail for one hardly may quietly and without doubt reduce it to a simple chance and coincidence. H. Becquerel who made this discovery recognized it clearly as I had shown.

Involuntarily the thought stops before such coincidences

H. Becquerel, *Op.cit.*

and seeks a scientific explanations for them.

The history of human scientific thought is a scientific discipline, i.e. it ought to try to connect scientifically the well established scientific facts, to seek for generalizations and to distribute these generalizations into a system and into an order. The discovery of radioactivity by H. Becquerel and the preparation (during three generations of the family of the physicists Becquerels) of this discovery by studying into the light properties of uranium is a scientific fact not to be easily got rid of.

We may not ignore this fact. If Laplace was but a little right and a mathematical formula ("Laplace's formula") can describe the rate of the world motion, world "life", we ought to expect manifestations of just such a type in scientific discoveries on the scale of the radioactivity discovery seen by us.

Already at this ground, we may not ignore this real coincidence of works with the rapidity of the discovery of radioactivity in the due time. Science does not know chances, and such coincidences in its history are not very seldom.[11] The success of the mathematical analysis after Laplace seems to me to make one admit that Laplace's metaphor had been right, in certain limits. But in what limits?

57. The consequences of the Bequerel's discovery permeated, all life of humanity, all its philosophic thought, and all its scientific world outlook.

Similar situation is represented by the consequences of the relativity theory advanced by A. Einstein 10 years after H. Becquerel. Einstein's reformation of physics already took place in the scientific atmosphere of the breaking of the old ideas. This breaking was caused by radioactivity, and this atmosphere was also the atmosphere of the victory and triumph of the atomistic world outlook. The relativity theory was generated by the scientific-theoretical and mathematical thought. Its history is far better known than that of radioactivity.

But also of the history of radioactivity, characteristic are a

[11] I tried to emphasize the radical significance of this feature of scientific knowledge (absent in other manifestations in the human spiritual life) already in my introduction to the lectures on the history of natural sciences that I delivered in the Munich University in 1902. Generally speaking, 1 still stay at this then formulated by me viewpoint.

modest beginning[12] and a continuos growth of scientific empirical material, of science facts tied up with the relativity theory in genetic and logical relations. This growth may be noted both with reference to intensity and variety. It is only this side of exact facts that ought to have the major significance for a naturalist (and not the side tied up with the mathematical and philosophical conceptions).

58. There is one more characteristic feature of the scientific knowledge that must be taken into account, for it plays the main part in the process which is taking place.

As we shall see in § 46, the part played by science in the social life is distinct from that of philosophy and religion in that it is essentially *unique for all times, social milieus, and state forms.*

It is true that the humanity comes to understanding of this fact through the grave experience of history for both religion and social state forms during millenia tried and proceed to try to create a unity and to include all people violently into a single integral understanding of the sense and the goal of life. There were no such unified understanding in the many-millenial history of mankind. Always the inimical or coexisting different understandings of the life sense and goal cohabited simultaneously. The unifying religious or state trend seems now to become an evident illusion for all. After a fruitless struggle and a lot of lost efforts, this trend begins to go into past. There had also been attempts of the kind in the history of philosophy, and they became a full crush as well.

One may let aside the social state units for from a noospheric viewpoint, they never embraced any significant part of the globe. Essentially, the so called world empires always covered certain land areas and coexisted. By force or by natural course of events, they became mutually balanced. It is only in our time that the idea about the united state organization of the humanity becomes real and evidently not more than a real ideal, in whose possibility one may not doubt. It is clear that the creation of such a unity is a necessary condition of the organized state of the noosphere, and the mankind inevitably will come to this unity.

The role of Poincare. The first work of Einstein. See about Einstein: D. Reichinstein. *Albert Einstein, gein Lebensbild und seine Weltanschaunpg.* Praga, 1935.

In the history of religions (which form they may take on: theistic, pantheistic, or atheistic), the real trend to unity was necessary, for they all had been founded upon faith and upon overcoming the rationalist's doubts as to their correctness. With an inevitability, life broke this trend, but the faithful ones believe in the realization of their ideal in spite of the bitter experience of generations. With the growth of science, the real importance of this faith in the world history rapidly decreases. For the Western Christian church, for the Roman Catholicism, any real possibility of such unity ended with the creation of the Protestant churches supported by the state force, and with analogous substantiation of the Moslem religious sects. The present deep crisis of religion deprives these unities the real historical ground in this relation. It is low probable that the atheistic ideas (essentially also an object of faith) based upon philosophical conclusions may acquire such strength as to give humanity a unified ideology. In essence, they also are religious conceptions based upon faith.

59. As to the philosophical thought, it is still less probable that it can create a unity, a universality of understanding. It is always based upon doubt and rationalistic substantiation of the existing things. There had never existed a period when only one philosophy was acknowledged true. Philosophy is always based on the reason and most closely tied up with a personality. The types of personality always answer the various types of philosophy. The personality is inseparable from the philosophical meditation, and reason never can include personality as a whole. Philosophy never solves the enigmas of the world. It seeks for such solution, it tries to embrace the life with the reason, but never can achieve that. Any philosophical truth may be always put under doubt by a free and searching personality. During the millenia of its existence, philosophy created the mighty human reason. It deeply and rationalistically analyzed human speech that had been elaborated during tens of thousand years in the milieu of social life; it worked out the abstract concepts, created such knowledge areas as logic and mathematics that form the base of our scientific knowledge. Also psychology (created by philosophy) begins to transform into a research area independent from philosophy. In this area, the predominant part is played by internal experience, by self reflection. This area of phenomena is frontierless and endless, it is just as deep as the reality which surrounds us.

Science grew out of philosophy several thousand years ago. It is very characteristic and historically important that we have three or four independent centers of the creation of philosophy which communicated mutually only during a few (two or three) generations, while during centuries and millenia they remained unknown for one another. The work of social, religious, philosophical, and scientific thought went in them independently during many centuries and even millenia. These were the Mediterranean, Indian, and Chinese centers. Perhaps one ought to add here the Pacific American center, which had been veiy late in relation to them and which is but little known to us. It vanished and perished in a historical catastrophe of the 16th century. During the generations close to Pythagoras, Confucius, and Sakya-Muni, the philosophic-religious centers of the Old World seem to have communicated mutually in cultural relation for some significant time.

A new exchange comparable to the first one had begun in more recent centuries. During many centuries, the philosophical thought developed in these centers mutually independently, with greatest strength in India and in the Hellenic-Semitic world. It is curious that in the course of the history of philosophy, we see an utter analogy in the historical process in the elaboration of both philosophical systems and logical structures. The Indian logic seems to go deeper than the Aristotelian one, and the course of the Indian philosophical thought almost a thousand years ago (with an accuracy of several centuries plus or minus; the chronology of the Indian philosophy still remains very imperfect) had reached the level of the Western philosophy of the end of the 18th century, i.e. it was in the 18th century only that our philosophy caught up with the Indian philosophical thought. During long centuries, the tradition of philosophical thought and its living perception never interrupted, but with the political decay of the Indian culture, the creative philosophical thought in India vanished, and in the 11th-12th centuries, probably Ramanuya (1050-1137), a great creatively thinking philosopher, was its last representative for many centuries. But the philosophical culture and philosophical interests did not stop, and some philosophical thoughts emerged from time to time up to the 17th century and later. In the 19th century, after the development of the living philosophical tradition during more than three thousand years, the renaissance of the self-dependent thought in India began at the soil of the universality of scientific knowledge under the influence of the European science.

It is more than a thousand of years that the Indian philosophical thought exerts profound influence upon the Tibetan, Chinese, Korean, and Japanese states.

This influence manifested itself, with great interruptions, during many centuries, and met the independently arisen philosophical search with its long and deeply rooted history that just begins to open itself before our eyes. Such was especially the case with the Chinese states, this self-dependent center of human culture. In the epoch of the decline of the Indian creative philosophical thought, the communication between European and the Indian philosophical search ceased and did not renew until our times. It was just the epoch when the ancient civilizations began to be influenced by the mighty incentive of the Western science.

60. The 19th and especially the 20th centuries, after the barbarous war of 1914-1918, radically changed the religious and philosophical structure of all humanity and created the firm foundation for a unified universal science embracing all humanity and giving to it the scientific unity.

This change began in the mid-18th century in North America where the English and French laid a foundation for the North- American scientific work. Still earlier, in the 16th century, this movement began in South America, in its Spanish and Portuguese cultural milieu, but in this region the movement soon vanished and did not create a firm scientific environment until the 19th century.

Altogether different was the case with North America where a powerful research center of the Anglo-Saxon scientific work emerged after continuous and incessant growth. This center is now the most mighty scientific organization of the humanity. In Canada, the old Anglo-French center of scientific work was conserved having merged with the Anglo-Saxon one.

In the 18th century, the principles of scientific search became transferred into the Moscovian Russia and, under state support, in a short time spread over the Asian continent, passing also to the north of America. Here, owing to the expansion of the Russian people, scientific thought and work became introduced into the life alien to the West in relation to its traditions.

The intensive development of the British colonial power and the specific nature of its policy influenced greatly the process of scientific integration of enormous areas. For this policy has led in the end of the 19th and in the 20th centuries to the creation of the British Empire which, so to say, integrated the entire Earth into a single cultural whole. Mighty and independent research work centers emerged in North America, Australia, New Zealand, South Africa (where in the 19th century, the Netherlandian-Afrikaans scientific center was formed). Not less important was the fact that under the influence of the English scientific thought, the ancient civilization of India and Burma became involved into scientific work, became embraced by the modem scientific thought and research work. In India and Burma, the scientific working centers became created; the scientific rebirth of India began based upon the united science and local specific philosophy and religion. Through the Indian thought, the people of the non- Christian philosophical culture are more and more infused into the scientific community.

More slowly went on the penetration of the modem scientific thought into the Moslem East environment of North Africa, Asia Minor, and Persia, i.e. in the cultural region which was at the head of world scientific movement in the 8th-12th centuries (but under the influence of the religious and political events, the scientific work slowly went out in these regions, and this process ended only in our centuries.

In the mid-19th century, after a many-century break, Japan became tied up with the West European culture and (like Russia 150 years earlier) created, by state measures, mighty centers of scientific culture and became basically connected with the world science.

At last, after the collapse of the Manchu dynasty, China joined the scientific work of the humanity. It is curious that, in the epoch of Peter the Great, China had been imagined (by the West Europeans and the Russians) to be a progressive country as to its importance for science history, and the Moscow Kingdom might deliberate about which side, East or West, it ought to turn, to join in the world science. In the 17th century, new science in its state applications penetrated into China through the Jesuits and other Catholic missions. Only in the early 18th century, this more than centennial work came to a downfall. Solely after the weakening of the Manchu dynasties, China formed steady research centers of its own. In 1693, the Chinese emperor Kangshi gave a wide tolerance in faith to his country, and the first exact knowledge application (in the form of astronomical observations in their applied and scientific significance) was introduced into the state system of China. In these times, China did not lag behind the Western Europe in what concerns technology, and its scientific foundations, and it was more mighty in science and technology than the Moscow Kingdom of that time. In 1723, when Kangshi died (several years before that he broke off with the Western science, from religious reason), China suddenly became backward, for the victory of the Newtonian world outlook and the new mathematical techniques to the mid-18th century raised the real state strength of scientific knowledge immensely. Kanghsi's mistake was heavily paid for by China, when in the 19th century China turned out to be helpless before the American and European occupation. The revival that began developing slowly in the mid-18th century led the Chinese to a stable consciousness of the necessity of mastering the strength of the unified science. Now the Chinese firmly adhere to this course.

61. So, in the 20th century, one single scientific thought embraced all the surface of the globe, all the states of the planet. In all them, many centers of research and scientific search have been created.

This is the first main prerequisite of the transition of the biosphere into the noosphere. Against this general and very diverse background, the 20th century explosion of the creativity in science is expanding, without any reference to the limits and demarcations of states. Every scientific fact, every scientific observation (independent of where and by whom they were obtained) enter the united scientific apparatus. Within it, they become classified and reduced to a unified form; become at once the common property for critique, thought, and research work.

But it is not such organization alone that defines the conditions of scientific work. They also include the favorable environment for the development of science, and this may be achieved by the most broad popularization of scientific knowledge, by its inculcation into school teaching, by the full freedom of scientific search, by its liberation from any routine, from the religious, philosophical, or social fetters.

The 20th century is a century of the great importance of the masses. In it, one sees a simultaneous and broad development of the most different forms of people's education. And also the mentioned fetters are far from being removed everywhere, they will inevitably be shattered with the further course of time. Enormous is the importance of the democratic and social organizations of the working people, of their international associations. The aspiration to obtaining the maximum scientific knowledge cannot stop. So far this side of the organization of the working people and their internationals did not correspond (in its rate and depth) to the spirit of time and did not receive enough attention. This work is being done now throughout the planet, independently of the frontiers of the states and nationalities. It is a prerequisite of the noosphere, necessary to the degree to which the creative scientific work is necessary.

62. This mighty growth of scientific knowledge, its increase in strength and area coincide in time with a deep stagnation in the adjacent fields of creativity closely connected with science: in philosophy and religious thought.

In the Western philosophy, in spite of its great and even ever increasing literature, the new creative work in our century is weak and not sufficiently deep. After a great flourishing of the philosophical work since 17th century to the beginning of the 19th centuiy, there appears nothing that could be compared with the scientific creativity of the 19th and the beginning of the 20th century. The contemporary philosophy is lost among details, does not touch the most important questions of life, repeats the old, is devoid of significance for a thinker who works scientifically. The old, dead since long ago ideas try and exist without any essential change in the new situation created by science alien to them. Only during the recent years these old trends recede, the new movement begins. But this movement already stands under direct influence of the new scientific thought and the new scientific world outlook created by this thought. There are also new the retical trends observed by a scientist working in the areas tied up with biogeochemistry and with the study of life in general. These trends are important for such scientist, and they are also connected with the influence of the new scientific thought upon him, when the science opens something new, it breaks the old philosophical ideas and indicates a proper way.

The problem is that there is a phenomenon in the history of philosophy impossible for the scientific thought of our time; the science is only *one* for the mankind, while the *philosophies are essentially many* and have developed mutually independently during long centuries and millenia, and through generations.

Along with the European-American philosophy, there exist the philosophies of India and China. It is true that the Chinese philosophy is in a somnolent state during many centuries, and the Chinese natural philosophy clearly contradicts the science of our time. But the Indian philosophy awakes now, distinctly and suddenly, after a many-centuries' latent (as to the creativity) state.

The Indian philosophical conceptions seem now to be of great interest for the new areas of science, and particularly of natural science. These conceptions only begin to revive after the many-centuries' stagnation, under the influence of the blossoming of the world scientific knowledge, and of the penetration of this knowledge into the spiritual life of the part of humanity that has managed to preserve, during many generations, the millenial achievements of the philosophical creativity of the ancestors. But the significance of these broad and perhaps deep philosophical conceptions of India for science is still to become manifested in future. Now, scientific thought goes ahead of philosophy in this area as well.

63. The religious consciousness of all mankind goes now through a deep crisis partly, but hardly as a whole, tied up with the growth of scientific knowledge and with the incongruence of the religious consciousness to scientific achievements, with its attempts to fight them.

For the first time in the history, the negation of religion as one of the cultural norms of the humanity is embodied in state ideology. In reality some states and great cultures, for example China, had epochs in their history when the religious understanding of the surrounding world was replaced by a state ideology. Inevitably and to some degree unconsciously, the same social structure as a form of the religious manifestation of life, the same obligatoiy social-state structure not susceptible to any doubt, is even now becoming clear in the anti-religious currents of contemporary thought. Practically it is a social-state religion, like the ancient Chinese one.

The mankind goes through the stage of a deep crisis of the religious consciousness and probably is on the eve of a new religious creativity. The old religious concepts ought to be deepened and rebuilt, first of all, under the influence of the growth of the scientific thought.

There is a passive state, in relation to the centennial great ideas, of philosophical thinking and religious consciousness of reality, of the understanding of life, particularly under the conditions of the scientific creativity explosion whose force is constantly on the increase. This state creates the importance of science which has never existed before in the science history and opens new research problems that acquire, under this aspect, new significance.

64. Another new phenomenon exists precisely in our 20th century and rapidly changes all conditions of scientific creativity and gives them a special character and a special significance never seen before.

Our time is essentially different and unusual in this reference, since it seems to be for the first time in the history of the mankind that we live under the conditions of the *united historical process that embraced all the biosphere of the planet.* Just finished are complex historical processes that took place independently and closely (partly so, during several generations) and in the end, in our 20th century, created a *united, inseparably coherent whole.* An event in the remote places of India or Australia may suddenly and profoundly influence Europe or America and have here consequences of an immense importance for the human history. And what perhaps is the main thing, the material, really continuous coherence of humanity and its culture incessantly and swiftly gains force and profundity. The communication is becoming more intense, various, and permanent.

The history of the past of the mental culture of the humanity is yet so little known now that we cannot represent clearly those stages of the past which had led to the contemporary *life universality* of the people embraced by it (by the unity of life), independently of their actual habitation in the biosphere. How one cannot hide oneself from this universality in the field of spiritual life, nor in the field of habitual life. And the rate of the fastening of this universality is so great that the now-living generations recognize it altogether really. One may not doubt it.

The universality and the coherence of all human societies is continuously growing which became evident during several recent years; all the more evident with almost each new year.

The scientific thought is a single one for all, and the scientific methodology (also one for all) has now embraced all the humanity and spread over all the biosphere transforming it into the noosphere.

This is a new phenomenon that gives a special importance to the now observed growth of science, to the scientific creativity explosion.

65. To that, one must also note that this essentially new phenomenon has begun its slow development in the 17th-19th centuries and became intensified by the late 19th century. In the 20th century, under the influence of the intense growth of scientific thought, the same phenomenon gave the most important significance to the applied role of science both in habitual life and in every aspect of everyday, private, and team life.

The state life in all its manifestations is covered by scientific thought to a degree never heard before. Science is to an ever increasing degree used in the needs of state life.

The importance of science in life is, as we shall see, closely tied up with the changes in biosphere and its structure. With the transition to noosphere, this importance increases at the same (or swifter) rate as the growth of the new areas of scientific knowledge.

And alongside with this growth of the application of scientific knowledge to life, to technology, to medicine, to state work, alongside with all this, new applied sciences are being created (and in greater numbers than in connection with the new theoretical realms of science) with the new techniques and very fruitful new applications; new problems and technological tasks are being advanced (in the broad sense of the word "technological"). The state means are being spent to an unprecedented degree for the essentially scientific, although applied activities.

The importance of science and its problems grows in life under the aspect with an even greater rate than the new knowledge areas do. And it is these new research areas that extremely enlarge and *deepen the applied importance of science,* the part played by it in the noosphere.

Section two ABOUT SCIENTIFIC TRUTHS

CHAPTER IV

Position of science in the present-day state structure

66. Such vital significance of science entering the consciousness of modem humanity is far from corresponding historically (that is, proceeding from the *past)* to its factual situation and its evaluation in life.

Modern social and state position of science in the life of the humanity does not correspond to the importance that it actually has in this life already now and practically. This is reflected by the position of the scientists in the society which they live in, by the degree of their influence upon the state measures of the humanity and of their participation in the state power, and, the last but not the least, by the evaluation (in the governing groups and conscious citizens, i.e. in the "social opinion" of a country) of the real force of science as well as of the special significance of its judgments and achievements for life.

Man has not made yet any logical inferences from the new foundations of the modern state life. The time we live through, the time of a radical and deep democratization of the state structure (although this democratization is not yet stable, but already strongly influences the forms of the state structure) this time inevitably must lead to a radical change in the position of science and scientists within the framework of the state system. Must lead, but still does not lead. The role (both political and social) of the popular masses and their interests sharply change the interests of the state. The old "raison d'etat" and the former purposes of the existence of the state based upon the historically established dynastic interests and interests of the classes and groups related to the dynasties—these "raison d'etat" and purposes are being swiftly replaced by the new understanding of the state. Before our eyes, the significance of the dynasties rapidly becomes the property of history alone. A new idea emerges which unavoidably (sooner or later, but still within a reasonable time) will overcome—the idea of the *state unification of the efforts of the humanity*. This idea may only be realized through a wide use of the natural means for the benefit of the state, essentially—of the popular masses. Such realization cannot take place but under a radical shift in the status of science and scientists in the civil organization. Essentially, this is the state manifestation of the transformation of the biosphere into the noosphere. As we had repeated several times, this natural process developing before our eyes cannot be reversed or evaded. One cannot doubt that the current position of science and scientists in a state is a transient phenomenon. One must take into account a rapid change in this position.

67. But for now, this change still does not take place. And this is expressed in especially dramatic way by the quantities of state allotments that are spent for purely scientific demands lacking any military (either aggressive or defensive) importance as well as any industrial, commercial, communicational, medical, or popular educational significance. Down to our times, there are no states that would (systematically and regularly within the civil demands or within what is thought to be such demands) spend much state money on the tasks far from the current life and realizable only in future, on the solving of major theoretical problems.

It is not still recognized by the common consciousness that the humanity can strongly enlarge its force and influence in the biosphere by creating the immeasurably better life conditions for the forthcoming generations: creating them through the conscious state scientific work. This new direction of the state activities, the objective of the state as a form of the new and mighty scientific search, cannot be thought of as an inevitable consequence in the nearest future (a consequence of the historical moment that we are now living through—of the transformation of the biosphere into the noosphere). But it must be thought of as an unavoidable geological process. I shall still return to this question.

Already now we see this geological process approaching. Practically, by the phenomena of life themselves, spontaneously and to higher and higher degree, science becomes incorporated into the state activities and acquires increasingly eminent position. But this is being done without any clear and conscious plan, although for the benefit of the case.

Such state of things is evidently transient: it is unstable from the viewpoint of the state regime and, still more important, from the viewpoint of the noosphere organization.

Proceeding from this situation and using their initiative, the scientists to an ever increasing degree apply (to the aim of increasing scientific knowledge) the state means which had not been consciously predestined by the state leaders for this purpose. In this way, the scientists acquire the ever-growing possibility to develop science by means of increasing its applied significance in the area of technology development that cannot be achieved in any other way. In this respect the 20th century made a great progress, whose significance and force remain latent and still not understood.

There is no adequate formulation of the requirements of science; their inevitability and advantages for the humanity remain unrecognized. There is no expression for these requirements in the social and state structure. One has not elaborated the legal forms that would permit to solve, in a swift and operable way, the international problems. And most questions of the creation of the noosphere are international in their budget or financial expression.

In the budgets of separate states, such questions (although elaborated only to a slight degree) may be, and are, touched upon in the state assignments for the needs of the academies (where there are such assignments) and in the state foundations for helping scientific work (where there are such foundations). In general, this help is too small as compared to the emerging tasks. It concerns in equal degree, both the capitalist states and our socialist state, if we count the financing in the unified golden currency.

68. But it seems to me that now we pass through a transition point. The public consciousness has recognized the state significance of science as a creative force, as a main element that nothing could replace in the creation of people's wealth; and as a real possibility for creating this wealth in a rapid and intensive way. It is evident that the mankind will not leave this way, for science is, in reality, a maximum force that creates the noosphere.

This creation, that makes the noosphere fully evident, will be accomplished in a spontaneous way, as a manifestation of the natural process. Earlier or later, the creation of the noosphere will become a purpose of the state policy and. social structure. This is the process rooted in the depths of the geological time, as one can see from the evolutionary process of the formation of the brain of *Homo sapiens* (see § 10). The powerful process taking place in the biosphere within the geological time and closely tied up with the energy manifestations of organic evolution cannot be shifted in its course by the forces manifesting themselves within the framework of the historical time.

A great and specific shift in the social ideology of our time is taking place now. This shift is not paid enough attention and is not sufficiently taken into account for one does not see consciously the above mentioned geological genesis of the scientific thought and its foundation that has been created by the evolutionary process. One does not see that scientific thought is an enormous[1]...

Since the late 18th century, when the churches in the European-American civilization became weaker, and in the epoch of the Enlightenment philosophy and later, the way became open for a more deliberate philosophical thought. In scientific thought, the philosophical trend became prevalent hardly separable or inseparable from the science contemporary to it (for example, the philosophies of the Enlightenment, of Leibnitz and his school, of materialism, sensualism, Kantianism); and, at the same time various manifestations of the Christian philosophies and idealistic philosophical systems emerged: Berkelianism, post-Kantian German idealism, mystical searches. From time to time, these trends began to oppose the scientific achievements and never thought themselves to be obliged to follow them, even in the areas of the positive scientific knowledge.

The illusory belief in the supremacy of philosophy over religion and science became clear and dominating. As to the science, this belief had deep roots, for often it is difficult to discern the generally necessary nucleus of scientific constructions from that part of science which is essentially “conditioned”, transient, and (with relation to logic) equivalent to the philosophical or reli

1 The phrase is not finished.-Edit. note.

gious explanations of the scientific knowledge domain.

This could (and can still now) take place, first of all, because of the fact that the logic of scientific knowledge, of natural science in particular, still remains in a non-elaborated, nonrethought critically, non-studied condition.

69. It is certain that now we must pay attention not to the artistic and utopian pictures of the future social organization but solely to the scientific elaboration of the social future, although in a literary form.

Here, we may leave apart the anarchistic schemes of the future. Until our times, they had found neither important manifestations, nor eminent minds who would elucidate with sufficient depth and novelty the anarchistic social structure which is vitally possible, although distinct from socialism, and tied up with the anarchistic modus of social life.

Both trends in the social life, anarchism and socialism, have justly appreciated the mighty and inevitable strength of science for the proper social organization that would give maximum happiness and full satisfaction of the main material needs of the humanity. In both trends, the scientific work of the mankind was recognized to be the means that could give sense and purpose to the existence of man and dispose with his unnecessary sufferings—his elementary sufferings here, on the Earth, such as hunger, misery, killing in war, diseases. In this sense, both trends of the thought, whether they proceed from scientific or philosophical constructions, fully correspond the concept of the noosphere as a phase in the history of our planet (and this is the concept which is ascertained empirically in this work).

The belief in the strength of science increasingly penetrated the thought of the Renaissance people, but it was also expressed creatively in the great and deep works of the first apostles of socialism and anarchism—Saint-Simon (1760-1825) and Godwin (1756-1836).

This search obtained real significance in the middle of the 19th century, in the works of the eminent scholars and politicians, K. Marx (1818-1883) and F. Engels (1820-1895), and in the consequences of these works, namely, in the social-state victory of socialism in the form of Bolshevism in Russia and in some parts of China and Mongolia.

K. Marx, an eminent scientist and a self-thinking Hegelian, recognized the great significance of science in the future socialist system that is to come. At the same time, he did not separate science from philosophy and thought that they, when correctly expressed, cannot be mutually contradictory. At that time, nearly a century ago, this view was completely understood. For K. Marx and F. Engels, philosophy was the main thing in life, it conditioned all their conscious life and influenced their spiritual essence. In their time, almost no one could foresee that they, contemporaries of a seemingly unprecedented flourishing of the idealistic German philosophy, contemporaries of Hegel, Schelling, Fichte, had really lived in an epoch of a deep decline of philosophy and emergence of a new world trend, much more deep in its roots and strength—a rapid progress of exact and natural sciences in the 19th century. In this connection, the reality did not justify Marx and Engels' representations: the primacy of science over the philosophical constructions now, in the 20th century, cannot raise doubt. But as a matter of things, the scientific foundation of the work by Marx and Engels is independent from its form, a survival of the 1840s, in which it had been clothed by them, who were the children of their time. Life gets its way and it is no use to argue with it.

In reality, the importance of science as the foundation of the social reconstruction in the social organization of the future is not inferred by Marx *from the philosophical ideas,* but had been a result of the scientific analysis of the economic phenomena. Marx and Engels are right having laid the base of the "scientific" (not philosophical) socialism, for they (mainly K. Marx) had elucidated the deepest social significance of scientific thought which might be seen intuitively from the preceding searches made by the "utopian socialism".

In this respect, the notion of the noosphere resulting from the biochemical ideas completely coincides with the main idea that goes through the "scientific socialism". I shall return to this question further on.

The broad expansion of socialist ideas and their influence upon the bearers of power, as well as their influence in many major capitalist democracies, all this created the appropriate form for the acknowledgment of the significance of the research work as creation of the people's wealth.

The new forms of the state life are created in reality. They are characterized by the penetration (in them, to an ever deeper degree) of the elements of the socialist state structures. The state planning of scientific work with respect to the applied state purposes is one of these manifestations.

But with the rise of the significance of science in the state life, inevitable is also, in the end, another change in the state construction: the strengthening of its democratic framework. For in the essence, science is *profoundly democratic.* There is no Hellene nor Jew in it.

One may hardly think that, under such primacy of science, the popular masses could—for a long time and everywhere— loose the position that they had acquired in the modem democracies. Taking into account the universal nature of science, the process of the democratization of the state power is a spontaneous process.

Of course, this process may last for generations. In the history of mankind, this creates the noosphere as a result of the geological history, one or two generations are a geological nought.

70. The consciousness of the radical importance of science for the "Good of humanity", of its enormous force for good and evil, changes the scientific milieu slowly and constantly.

Already in the utopias, even in the ancient Hellenic utopias (Plato), the state power was thought to be concentrated in the hands of scientists. This thought is more or less manifested in almost all utopias.

But the growth of the state role of scientists (this growth is already being observed) influences greatly the organization of scientific community and changes the social meaning of the scientific milieu.

The old extra-state unity of scientists, characteristic of the 16-17th, partly of the 18th centuries (the epoch of the small states in the Western Europe and of the predominance of a single scholar language)—this unity lost its importance in the 19th-20th centuries, when the growth of states and the growth of science led to the rise and to the pressure of the national and state patriotism. The scientists of all countries participated in this movement to a great, often predominant degree, for the real interests of science (the universal human interests) faded away or receded to the second place before the imperatives of the social or state patriotism. But at the same time, in connection with the civil demands that went side by side with the aims of the scientific knowledge and with the development of some interstate units (which led, after the war of 1914-1918, to the League of Nations), in the 19th century, numerous and diverse scientific unions at the global scale emerged. After the war of 1914-1918, they suffered a great loss and still are far from having achieved again the pre-war level.

71. The war of 1914-1918 and its consequences, namely, the growth of fascist and socialist moods, disturbed deeply also the scholar world. Still greater influence was exerted by the uniting of the humanity in a whole, which long before had been prepared and manifested itself, in the unprecedented degree and rate, in the cultural exchange owing to the successes of science in the area of human communication. The war had the deepest consequences which could not fail to influence the social status of science. One of these consequences is a deep moral feeling in the learning community of the world tied up with the terrors and atrocities of the greatest crime to which the scientists have been the active accomplices. Really the war became recognized as a crime by many scientists that took part in it. The moral pressure of the national and state patriotism that made many scientists to participate in the war now became weaker and the moral side to this participation was inevitably advanced in scientific work and first showed itself up to scientist as an *everyday phenomenon.* This moral side of the scientist's work was his moral responsibility for this work: the responsibility of the scientist as a free personality in the social milieu.

Thus advanced is the question of science's moral aspect, independently of the religious, civil, or philosophical manifestations of the moral.

This problem is now occurring to be a real force that will be dealt with to an ever increasing degree. This situation has been prepared by a long, still unwritten, even unrecognized his tory.[2] The question of the moral side of science stands altogether outside of the so called scientific moral that one tries and creates now in the form, for example, of the *moral laique* of the French state. This *moral laique* is a social and philosophic construction, which has (if one analyses its content) a complicated and distant relation to science. This is something very different from the appearance of the moral element in the scientific work to which I shall return in another place of this book. This is the case when the name does not answer reality. It is the moral that is connected not with science but rather with philosophy, and real requirements of the state policy, with an attempt to replace the religious Christian moral. This attempt appeared as a result of the prolonged struggle for religious tolerance as a compromise between the ideas of the French revolution and the real strength of the pressure of the catholically thinking citizens. To an equally low degree, can such deep movement (which since 1914 more and more expands over the wide circles of scientists) be answered by a state moral, whichever it may be; or by an old religious ethics. The transient form of the democratic political system is a superficial phenomenon, which is too fine for the personal moral of a contemporary, future-oriented scientist to be built upon. Already now, the historical process introduced a deep change into the concept of democracy for it revealed the importance of the economic base of the state structure, and an equal efficiency advanced the idea of state unification of all humanity for the creation and realization of the noosphere—for the use of all strength of science for the good of all the mankind. Such a democratic ideal of a scientist is worlds apart from the civil moral of the French radicals.

72. The state moral of a united state, although be it a socialist state, in its modem form can not satisfy the critical free thought and moral consciousness of a modem scientist, for it does not give the forms which are necessary for this goal. Once gener- 'j

Strangely enough, one still can frequently hear that science does not know good or evil, just as the nature knows neither good nor evil, as it will be shown in §101, the nature (when we deal with the living nature) is the same as the biosphere.''Good" and "evil" is a creation of the noosphere, just as all such phenomena are. In the noosphere, a scientific moral is possible whose weak expression is the utilitarian moral of Brentham and his followers. It is to be discussed in more detail in the end of the book.

ated in scientific milieu and unsatisfied, the feeling of the moral responsibility for the existing situation that appeared with the scientists, and their belief in their real potential of action can not vanish from historical scene without some attempt to become actualized.

This moral discontent of a scientist never ceases to increase. It is growing since 1914 and feeding all this time on the events of the world environment. This discontent is tied up with the deepest manifestations of the personality of a scientist which are critically checked by the scientific thought in the process of the observation of the course of natural phenomena.

73. In the past history of mankind, there was an attempt at creating a state moral. This attempt had been undertaken in the great (though isolated from the other ones) cultural center, namely, in China, when the geological force of scientific thought hardly manifested itself and was not recognized.

In the construction of the Chinese states, more than 2000-2500 years ago, the idea of selection of the outstanding people in the state had been implemented. This idea had been based upon the wide competition within the framework of the all-state scholarship, to create the scientific estate into whose hands the state power should be transferred. In principle, this selection of the statesmen had existed during many a hundred of years. It had been connected with the name of Confucius and really put into practice.

But the science, as it had been understood in this context, was very far even from the real science of that time. It was rather scholarship, a great culture over a deep moral base. It did not give to the scientists who governed the state any new real force. When in the 16th—17th centuries China met the rapidly enforcing new Western European science, it tried, for some time, to introduce it into the framework of its traditional erudition. But by the early 18th century this attempt, as I have said in §60, ended in a full crush, and certainly this peculiar historical phenomenon is far from the situation which now is being dealt with by the world scientific community.

In the 20th century, with the downfall of the old China, the remnants of the old Confucianism had been wrecked too. The united scientific thought, the united team of scientists and the united scientific methodology had entered the life of the Chinese peoples and now are exerting swiftly their influence in their scientific work. One is hardly to doubt that the wisdom and moral of the Confucianism (which lasted for millenia and remained alive merging with the united world science) will tell deeply upon the course of the world scientific thought, for in this way, it acquires many new personalities with a scientific tradition more profound than the West European civilization. This will be expressed, first of all, in the understanding of the main scientific ideas at the interface between science and philosophy.

74. The war of 1914-1918 sharply weakened the international organizations of research workers that had been created during the 19th-20th centuries. They have not yet regained their truly international (in the form, interstate) nature. The deep historical discord between fascism and democracy-socialism, at the present historical stage, and the acute aggravation of the intrinsic state interests relying on force (in several countries), eventually on the new war, for obtaining the better life conditions for their population (including such countries as Germany, Italy, Japan—the mighty centers of scientific work with a rich and organized scientific apparatus), all this gives no possibility for expecting a swift and serious bettering in this respect.

One may not miss to note that the new forms of the international fraternity begin to be sought for and become visible: that is, the *extra-state organization forms* of the world scientific environment.

These forms are more flexible and individual and are now at a stage of a trend, of the shapeless and still not balanced quest.

But during the recent (1930s) years this quest obtained the first beginnings of the organization and manifested itself explicitly for everybody: for example, in the “brain trust” of the Roosevelt’s consultants that has drawn much attention and exerted great influence upon the state policy of the United States; this “brain trust” became a real factor to be reckoned with.

It is evident that this is a form of intrastate research organization with a great future. Still earlier (in idea, not in accomplishment) and in more bureaucratized form, the Gosplan was created in our country, presenting a structure of the same order.

The idea of a “scientific brain trust” of the mankind is being advanced by the life itself, and this slogan finds repercussions.

This idea was discussed also in the public sessions during the celebration of the 300th jubilee of the Harvard University at Boston and Cambridge in 1936. But the main importance of these celebrations consisted in the personal communication between the eminent researchers which came together at this feast. The thought became conceived.

It seems to me that it is possible (and more than that: probable) for this idea to have a great future.

It is difficult to say which form will it obtain during the nearest time. But it is hardly to quit, even for a time, the historical scene which it came to occupy. Its roots are intimately connected with the course of scientific thought and feed on it incessantly.

CHAPTER V

The necessity and obligatoriness of the correctly inferred scientific truths for every person, for every philosophy, andfor every religion. The universal obligatory nature of scientific achievements (within the competence of science) is the main distinction of science from philosophy and religion, whose conclusions do not have such compulsory nature.

75. 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 phenomenon consists in the *compulsory and indisputable nature of the correctly made scientific conclusions, scientific assertions, scientific concepts and inferences.* The scientific, logically valid acts have such force only due to the fact, that science has a peculiar structure and that an *area of facts and generalizations* exists within it that relates to scientific, empirically established facts and empirical generalizations that in their sheer essence may not be disputed. Though philosophy, religion, wisdom of ages, social common sense or tradition may sometimes produce such facts and such generalizations, they cannot prove

them as such. Neither philosophy nor religion, nor common sense can establish the facts and generalizations with the degree of certitude given by science. Their facts, their conclusion and inferences are to be tried at the touchstone of scientific knowledge.

This general obligatoriness of a part of scientific achievements is sharply distinct from their another part which is to be assumed for the axioms, the self-evident notions lying at a basis of the main geometrical, logical, and physical ideas. Perhaps this distinction is not a fundamental one but it is tied up with the fact that during many generations and through millenia these axioms became so evident that man can ascertain their correctness by the force of a single logical process. But, perhaps, this is tied up with the structure of our reason, i.e. after all, of our brain. Perhaps this is the way through which the noosphere manifests itself in the thinking process.[1]

For the purposes which I deal with in this book I am not to stay upon this question which is still not sufficiently deepened scientifically and philosophically and does not possess solutions upon which scientific work could be based substantially. In distinction from the axioms, the obligatory scientific truths are not self-evident and must be tested (continuously and in all cases) by the comparison with reality. This real testing is the main everyday work of a scientists.

All other spiritual constructions of man—philosophy, religion, artistic creativity, the social everyday milieu of common sense, the secular tradition—lack such obligatoriness and indisputability of their assertions and conclusions. But more than that: we have no possibility to decide, to which degree are true and correct even the assertions (on man and his real world) of the most basic religious and philosophical conceptions—letting alone the poetic and social viewpoints with their evident (as the experience of many centuries shows) arbitrariness and subjectivity of assertions. At the same time we know that these assertions contain a certain (sometimes rather great) portion of truth, of the scientifically true understanding of reality. This portion can be revealed in

[1] See about the axioms: A. Eisler, *Worterbuch der philosophisihen Begriffe. Historisch-quellenmassig bearb,* Auff. Hrsg. unter Mitwirkung der Kunatgesellschaft, Bd. 1. Berlin, 1927, S. 161

man profoundly and completely: in the artistic images that cannot be conceived by reason to their depth, in the musical harmony, in the ethical level of personal behavior.

These areas are the fields of the deep manifestations of personality related to faith, intuition, character, and temperament.

Both religious and philosophies, poetical and artistic expressions, common sense, traditions, ethical norms may be numerous: taking as a limit, their number may be equal to the number of separate personalities (if one takes into account the nuances), and in a more general sense, equal to the number of personality types. Still, science is *one* and united, for although the number of sciences increases constantly, and although always new and new sciences are being created, they all are interconnected in a single scientific construction and cannot logically contradict to one another.

This unity of science and diversity of the reality treatments in philosophies and religions (from the one hand) and the indubitability and (essentially logical) obligatoriness of a great part of the content of scientific knowledge, finally of all the scientific progress (from the other hand), distinguish science sharply from the adjacent philosophic and religious assertions that deeply penetrate into the thinking of the research workers.

With an evident growth of scientific material, the strength of science increases, and so does its geological efficiency in the environmental biosphere, the role of science in the life of humanity grows and its vital influence increases in a rapid way.

76. One may easily see that the indubitable force of science is only tied up with a negligible part of scientific activities. This part is to be considered as the *main structure of scientific knowledge.* We shall see that it had a complex history and did not develop simultaneously in various countries. This part of scientific knowledge covers *logic, mathematics,* and that approach to facts which may be called *scientific apparatus.* Science is a dynamic phenomenon in a constant change and development, and its indubitable force becomes fully clear solely in the epochs where these three cardinal manifestations of scientific knowledge (logic, mathematics, and scientific apparatus) *synchronously* grow and deepen.

As to mathematics and logic, they always were acknowledged in their relevance and indisputability (when correctly used). But scientific apparatus was not, up to this time, paid enough attention by thinkers and even scientists themselves. They did not think it to be one of the main results of their work. Instead of that, they advanced as such the hypotheses and theories which represent the explications logically always connected, to some degree, with this apparatus.

In the everyday life, where the interests of the material existence of social life, or philosophical and religious, prevail, the consciousness of an extraordinary significance of the scientifically established facts is not yet developed sufficiently. The scientific apparatus is deeply imbued by and based upon the systematization and methods of research which are constantly going better and deeper. In this way, and every year, science embraces and fixes (for the future, and at an ever increasing rate) millions of new facts. On this base, science creates many major and minor empirical generalizations. But neither scientific theories nor scientific hypotheses (notwithstanding their importance in the current research work) are included in this main and decisive part of scientific knowledge.

But one ought to remember that without scientific hypotheses, the empirical generalization may not be exactly formulated, and that a significant part of the facts themselves, of the scientific apparatus as such owes its existence to scientific theories and scientific hypotheses. Scientific apparatus must always be taken into account, and every scientist in his estimation and empirical generalization of facts must admit a possibility of fault for some external influence can distort the facts within the framework of any scientific theory or hypothesis.

The main significance of theories and hypotheses is a seeming one. Notwithstanding their enormous influence upon scientific thought and scientific work of a given moment, they are always more transient than the indubitable part of science which represents the scientific verity and survives hundreds and thousands of years, perhaps even is created by an Eternal Reason and transcends the limits of historical time (as something "timeless" and immovable in geological time).

Thus, the main indubitable eternal framework of science (far from embracing all its content but embracing the rapidly developing in volume sum of knowledge) consists of (1) logic, (2) mathematics, and (3) scientific apparatus of facts and generalizations. The scientific apparatus grows incessantly as a result of scientific work in a geometrical progression. As to the scientific facts, their number already far exceeds our usual numerical habitudes : it is of the order 10^{10} or even 10^{20}. They are as numerous as “sand in the sea”. But these facts are reduced to such form that scientists in their totality (science of the given epoch) can easily and appropriately use them. Innumerable empirical generalizations may be built up upon this apparatus logically and sometimes even mathematically.

This main part of science absent both in philosophy and under the religious construction of the world becomes overgrown by scientific hypotheses, theories, leading ideas, sometimes conceptions whose absolute reliability may be put into question.

Such state of science in the social system of humanity places science, scientific thought and work into altogether different position and determines its peculiar significance in the noosphere as the milieu of manifestation of the reason.

77. This notion of a special place of scientific truths and their compulsory (for all) nature down to these days has not been accepted by all. More than that,' one is to take account for the opposite notions. The idea of the compulsory nature of scientific truths is a new achievement in the history of culture: one which begins to work its way in the consciousness of humanity.

Religious ideas based upon the faith in a special nature of religious truths are still far from being overcome. This faith includes the notions on religious truths as revelations of Deity which may not be disputed and ought to be conceived as an absolute, obligatory, and incontestable truth for all: for those who believe and who does not believe. With relation to religious ideas, only after great and prolonged suffering and struggle a compromise has been achieved in many Western European and American states. A possibility has been created actually not to reckon with the religious assertions (ideologically dynamic and formally dominating) of the believers of Christian, Judaic, Moslem and other churches possessing a real force. Yet to some (insufficient) degree, freedom of scientific thought is secured.

Since the late 19th century, with fluctuations to one or another side, the concept of the compulsory (to a degree exclusive in the given social conditions) nature of scientific truths has been receiving ever greater real force. But the results may not be taken as secured and stable even with relation to simple tolerance, i.e. with relation to acknowledgment of their force on a level with religion and philosophy. Struggle has not been finished yet. For an overwhelming mass of humanity, religious truth is higher and more convincing than scientific truth, ought to fall back before the religious one, and science must recede in case it contradicts religion. But it cannot recede, owing to its very nature.

As a whole, struggle evidently seems to lead to the triumph of scientific knowledge. In the 20th century, the victorious movement of scientific thought (in relation to softening of religious restrictions and freedom from them) irradiates all over the humanity. The East of Europe, all Asia and Africa, South America and oceanic islands are seized by this movement. With the inclusion of the greatest center of the multi-millenial culture, India, into the modem scientific work, with the revival of its free scientific and philosophical thought in the 20th century after many ages of stagnation, the organization of science obtained new strength, scientists, for whom the religious consciousness left during centuries *a complete freedom* of scientific search. It seems to me that one must take into consideration, for the future, this new intensifying of humanity's scientific work.

78. During the past time, we have lived through the deterioration in this realm, for the religious pathos of the faith in the necessary future unity of the religious understanding of man and reality grows weak and is replaced by the transient social and state concepts guarding themselves by brute force from eventual doubts in their immutability. An essentially new social form of life emerges very unfavorable, even ideologically, for the freedom of scientific search.

In essence, this is tied up with the negation of such freedom of thought and scientific search which has been obtained in the 20th century in the democratic states of Europe and North

America, first of all, in connection with and in time of the struggle for the freedom of religious faith, after the failure of the attempts of the Roman Catholic church to exterminate those differently believing. During centuries, in the complex political and social circumstances, the ecclesiastical pressure softened but state power used the same pressure media for the struggle with the freedom of scientific thought, as well as with social and political opponents. Under the current course of state work, scientific thought essentially ought not to come into collision with state power, for *science is the main, principal source of the wealth of the people, and the base of the force of state.* Struggle with scientific thought is a pathological, transient phenomenon in the state structure.

Struggling also against the religious beliefs, state power fought against not with their ideology, but with their harmful (from the viewpoint of state power) manifestation in that social-political environment which was the main subsoil of the state power. Class, party, and personal interests, as well as the conservation of an unequal distribution of popular wealth, not securing wealthy life for all, defined the state policy. They also defined the state policy in the question of the freedom of faith and in the area (to some degree, tied up with this question) of the freedom of scientific creativity.

79. Only in a few countries, rather complete (still not absolutely complete) possibility for the free scientific search was obtained. Most fully it was realized in the Scandinavian countries and great Anglo-Saxon democracies (but, for example, it is not the case of India, a part of British empire) and in France, perhaps in China.

In our country, this possibility has been never achieved, and it is also absent now.

In a number of states, this state restriction of free scientific thought has been transformed into a state religion, explicitly or implicitly.

It is a state religion in Japan within the framework of the doctrine about the emperor as a descendant of Sun. State regards any doubt in this dogma as a crime, and all children are taught it in all schools.

Ideologically less clearly it is manifested in the fascist states (Germany and Italy) and in our Socialist state. In the Czarist Russia there have existed continuos attempts to create a state religion, with reference to its dogmas—a political religion, how S.S. Uvarov has defined it a hundred years ago[2]. Under the complete subordination of priests to state, religion had evidently political nature and implicitly contradicted public opinion which could not be freely expressed.

Now we live through a transitive period when an immense part of humanity has no possibility to judge correctly about what is happening. Thus life goes against the main condition of the formation of noosphere.

It is evident that this is a transient phenomenon.

80. In this struggle, state power goes essentially against its own interests, supporting not the might of state but a certain social system, and this struggle is a manifestation of more profound features than those revealed by the economic structure of society. They are peculiar to the capitalist and socialist (and anarchic?) state formations.

During ages, the struggle between society and state power for freedom of thought has been founded upon the trends to conserve or destroy the existing social and economic distribution of people's wealth, to establish or abolish the religious understanding (in a state sense) of life, to secure the interests of power or its opponents. This trends now have been revealed clearly and really.

Under such conditions, the roots of the present social-state pressure on the freedom of scientific search have proved to be less profound after their ideological substantiation (the religious foundations of state policy) became less important. This pressure became more real and clearly more transient.

The social-state pressure upon the freedom of scientific search cannot stop scientific thought and creativity for long, for the modern social-political state life in its foundations and in its strength becomes more and more permeated by the achievements

[2] Uvarov told about this very definitely to Dvigulskii, rector of Moscow University, in 1832. He said about a "political religion" with two immutable, like Christianity, dogmata: autocracy and serfage. See: N. Barsukov. *Life and Works of M.P.Pogodin.* Vol. 4, SPb, 1891, p. 98 (in Russian); A. Ivanovskii, *I. M. Snegirev. A Biographical Sketch.* SPb. 1871, pp. 113-115 (in Russian).

of science and dependent on it.

Such state formation in the noosphere inevitably is fragile: at the end of the ends, science is the real decisive factor in the noosphere.

With necessity, this fact ought be revealed also in the state structure. The interests of scientific knowledge must come forward in the current state policy. The freedom of scientific search in the main prerequisite for the maximum success of research. There must be no limitations of this freedom. The state which gives maximum freedom to research and raises minimum obstacles to it achieves the maximum strength in the noosphere, is most stable in it. The frontiers, as we shall see, are laid by the new ethics, tied up with scientific progress.

This is inevitable, for the progress is connected with a complete transformation of the biosphere into the noosphere, and such transformation is a spontaneous natural process. When this transformation will be over, there should be no obstacles for the freedom of research in the noosphere, owing to the very essence of its structure.

81. More complex is the correlation between science and *philosophic doctrines* upon which also the state system practically depends not acknowledging freedom of research. Such or another philosophic system replaces at that the disappearing religious ideology.

The position of philosophy in the structure of the human culture is very peculiar. By inseparable and numerous ways, philosophy is tied up with religious, social-political, personal, and scientific life. The place occupied by philosophy with relation to religion is changeable, and there exists an enormous and growing range of interpretations and presentations of philosophy. An immense and ever increasing number of problems actually and eventually related to philosophy, the continuous transition from it to all questions of the everyday and state life, common sense, and ethics gives every thinking man who reflects on what is taking place a possibility to participate in the work of philosophy. Every self-conscious person in its everyday and social life is preparing itself for philosophy as well as for religion.

One may be a philosopher, and a good one, without any scholarly preparation: one only ought to reflect on the surrounding world in a deep and self-dependent way, to live consciously in one's environment. In the history of philosophy, we constantly see metaphorically speaking, rank-and-file people who prove out to be philosophers without any extra training. One can perform a deepest philosophical work, approach immense philosophical achievements within oneself, simply reflecting on one's self, deepening into oneself, even independently of the events in the world external to his personality.

Beside that, one teaches philosophy, and actually philosophy is something which can and must be taught. The works by eminent philosophers are among the greatest monuments of the understanding of life and world by deeply thinking personalities in the various epochs of the history of the mankind. These are the living human documents of utmost importance and instructivity, but they cannot be compulsory in their conclusions and inferences, for they reflect (1) first of all a human personality in its deepest meditation about the world, while personalities may be infinitely different and none two of them are identical; (2) the concepts of reality elaborated in these works. Such concepts are, according to very essence of things, non very numerous. They may be joined into a small number of main types. But there can be no unified concept more true than the other ones. There is and can be no clear and definite criterion for estimating such truths.

The formulated view on philosophy and its position in the cultural life is not a prevailing one. The clear distinction between philosophy and science introduced here is not generally accepted and may meet objections. But the main thesis (about the coexistence of many different philosophies among which one cannot choose logically a single one with respect to its verity) is an indisputable fact. One may only believe that this will not ever be the case, although the situation has always been such.

For my aims, it is enough to base oneself on this fact, in its above expression. In our epoch, of the ubiquity of human life and general indisputable compulsion of scientific facts and scientific truths (correctly established by research), it is right and necessary to separate clearly philosophy and unified science, without further anticipating whether it will always be the case or no.

82. From the said it is clear that one is to be taught philosophy but one cannot become a philosopher with the only help of teaching. For the main feature of philosophy is the internal sincere work of reflection on the surrounding world as a whole, or on its parts.

Philosophy is based upon the *primacy of the human reason.* Philosophy is always rationalistic. Thought and the deepening into the thought apparatus, i.e. the reason, is an inseparable part of philosophical work. For philosophy, the reason is the supreme judge; the laws of reason define the judgments of philosophy. This is the supreme principle of knowledge. For a naturalist, the reason is a transient manifestation of the highest forms of life of *Homo sapiens* in the biosphere transforming it into the noosphere; the reason is not and cannot be the final and maximum form of the manifestation of life. Human brain is not such final manifestation. Man is not "the crown of creation". Philosophical analysis of the reason can hardly give a remote idea about the possible power of cognition at our planet in its geological future. So far as we know about the growth of the reason with the course of time, there is no base for such an idea with relation to all the millenia when science had existed. But one ought not to reject such possibility as a real one. During tens of millenia, the thinking apparatus of man probably or even necessarily may change.

The main base of philosophy is the deepest analysis of reason, and more than that, of the psychic revelation of the living self in its maximum manifestations. This base of philosophy cannot give a criterion for scientific knowledge, for its contemporary *scientific apparatus* (inevitably related to the *future of the noosphere)* gives to this knowledge a scientific empirical basis which is far more powerful and firm than the said basis of philosophy.

Both science and philosophy have in common the process of reflection, i.e. application of the reason to the understanding of reality. This process still must have (in the connection with the above said) another nature in these manifestations of the spiritual life of personality.

With relation to the process of philosophical reflection, a question arises whether these exists a special area of philosophical cognition, a special manifestation of the reason which permits philosophy to discover new manifestations of reality: the “internal experience”. This question stands before philosophy during centuries and still remains unsolved, for up to these days many philosophers reject this question and try to refute logically its formulation, while the other philosophers try to answer the question positively and cannot find proves.

Reflecting about the reality, philosophers have always introduced into it (and with right) the reason as their own cognitive apparatus and submitted the reason to the same process of reflection on it which had been applied to the “external reality”. Nevertheless the validity of this submission remains spurious.

Science is alien to this reflection, first of all because it takes too much time and special knowledge; introduction of such reflection into the everyday work of scientist would leave him no possibility for his main research thinking.

I shall not dwell upon this side of philosophical work for it exceeds the limits of those achievements of philosophy which can interest a naturalist working in the new knowledge areas, among which one may also name biogeochemistry. For in these areas, the philosophical work is still lacking concerned with the analysis of new leading concepts, upon which these areas are built up: these concepts are often alien and new for philosophical thinking. This philosophical analysis necessary for the growth of science is inaccessible for a scientist, as I have said, simply because of an indispensable economy of thought.

Before such work is done by philosophers, and before a new philosophical contribution of scientific search into our epoch of scientific creativity explosion, is elucidated—before all that, a scientist working in these new areas of knowledge must wait and keep aside the judgments of philosophers who still cannot embrace an immense number of essentially new facts, phenomena, and empirical generalizations by philosophical analysis, as well as of scientific theories and hypothesis which are continuously being produced by scientific creativity. For a scientist, it is perfectly clear that without the above work over new material, a philosopher would come to distorted conclusions.

Further on I shall return to this question; but so far as philosopher’s work is directed to reflection over reality as such, over natural bodies, and over particular phenomena of reality, no scientist may ignore the work of a philosopher, may not but use this achievements. Nevertheless, he may not give this work the same importance which he gives to the core part of his knowledge.

Addressing real manifestation of philosophy in the culture of mankind, we must take into consideration the existence of many more or less mutually independent, similar or dissimilar, mutually contradicting philosophical systems and conceptions. Many of them do not have successors, yet they can influence life owing to the availability of accessible for all published expressions.

Among these systems and conceptions, one can find the mutually contradicting and exclusive ones, positive and negative, optimistic and pessimistic, mystical, rational, and “scientific” ones.

One may not speak about their concordance and about finding some unified, all-covering, general conception[3]. On the contrary., the attempts at creating a unified philosophy compulsive for all have long begun in the past. In our socialist state the attempts at renewing such attempts are made by means of creation of official, obligatory for all dialectical philosophy of materialism. Owing to the rapid and deeply penetrating movement of scientific knowledge, these attempts are doomed. These days, after twenty years of such attempts, one may hardly doubt that life itself without any struggle clearly shows their ephemeral importance.

The power of philosophy lies in its wide-range heterogeneity.

With the course of time, owing to life’s growing more complex and deep, owing to the increase in the scientific knowledge, to the appearance of new sciences and new scientific problems and discoveries of immense importance, the variety of philosophical ideas in our days is growing to a degree never seen before. This notwithstanding, a philosopher is in ever increasing degree falling behind the purpose of the philosophical processing of scientific knowledge.

[3] I do not discern here between metaphysical and philosophical conceptions, which influence scientific notions in a similar way and are to be reckoned with, equally for both.

83. The position of the modem philosophy of the West becomes all the more complex owing to the existence beyond it (in the East, mainly in India), of another group of great philosophical constructions which had developed self-dependently, out of any serious contrast and influence of the Western philosophy, and lived for many centuries the life of their own. This complex of philosophical constructions evolved without the influence of monotheism, in a distant to us religious atmosphere, in the high mountainous areas of the South, among tropical nature altogether alien to a Western European, whether he is a Christian or Jew, and within different artistic or social environment.

The greatest historical-cultural fact which now begins to manifest the depth of its significance is the profound and inseparable connection (already in the late 19th century) of the Western *scientific knowledge* with the scientists or in general with the people influenced by the great Eastern philosophical constructions alien to the scientists in the West. But up to our time, the philosophical thought of the West has but feebly reflected this entering of the living but alien to it philosophy of the East into the Western philosophical thought. This process is only beginning to manifest itself.

The scientists alien to our philosophical and religious culture and representing the largest, as to number, part of humanity have entered scientific work as equals and now occupy in it an equal position. It is clear that in no long time, the situation will be elucidated unquestionably and give the consequences not taken into account by the Western philosophy.

Research is intensifying all the time and receives more and more perceptible influence of the people of another religious-philosophical cultures than our European-American one.

We shall still see that the new areas of natural sciences, and biogeochemistry among them, find in the Eastern philosophy more interesting for them and important reasoning than in the philosophy of the West.

Under the influence of the modem science, and first of all of the new areas of knowledge, the Indian philosophical work has achieved a Renaissance at the basis of the *Indian ancient philosophy and the modern world science*[4]. This renaissance occurred

[4] See: S. Radhakrishnan, *Indian Philosophy*. Vol. 2. London, 1931, p. 778

after a many-century interruption and, perhaps, in connection to the unexpected closeness of the Eastern philosophy to the new scientific concepts. The Indian philosophical work reviles and takes a renaissance, it is in an increase while the Western philosophy still is on a decline, with reference to its creative force.

It may seem that, under such a chaotic state of the philosophical thought in the 20th century, under the absence in it (in the West) of any living and large-scale creativity, under the impossibility to find a criterion for the truth of its assertions, and under the existence, at the same time, of the equal (as to value) and differently living philosophical ideas in the East—under such situation, the Western philosophy would only have a second-rate importance for the scientific thought in its creative rise. In reality this is not so, especially in the times when new sciences and new knowledge areas (previously alien to science) emerge, whose problems still remain entirely the domain of the centennial Western-European creativity, mainly on the philosophical and religious scope.

The main thing is that a philosophical analysis of the abstract notions that are generated, in great number, in science, in its new problems and disciplines, is *necessary* for the scientific coverage of new research areas. As a general rule, no scientist can here go as deeply as a philosopher can, owing to the technique of the philosophical analysis requiring many-years' preparation. To that, scientific assertions are far from having (all of them) general obligatoriness. Philosophy does not at all estimate them as such, and doubt may long exist with reference to the logical value of the main scientific inferences. This must be expressed with a special evidence in new sciences and in the new (in their essence) problems. It is true that precisely here the centennial philosophical preparation of thought often turns out to be still more feeble.

In the areas that have been recently covered by science (such is the current situation) we meet the ready ideas formed or formulated by the philosophers before these ideas have been assimilated by science; and science has to count with these ideas, ought to overcome them. Partly they do not answer reality, but partly and to a certain degree they correspond to that explanation of reality which is first given for these areas by the new scientific knowledge. One must only refine them and connect them to the new understanding of reality.

But the current explosion of scientific creativity is not only tied up with the origin of new areas of scientific knowledge, of new sciences (§ 94): it goes through the frontier of scientific creation, changes abruptly and profoundly all scientific concepts, even the most ancient ones, even such basic ones as e.g. time and matter; is reflected by all the content of science and by its most traditional, immovable for long time achievements.

But beside that, science and philosophy are in an unceasing and most close contact, since both relate to one and the same (under a certain aspect) study object.

A philosopher deepens into himself and ties up with this systematic thought *of his own* the picture of reality, within which he also enters many profound manifestations of personality, which are hardly touched or touched at all by science. In this process, as I had mentioned, through his methodology elaborated during generations, he introduces logical profundity generally not accessible to a scientist. For this profundity requires a preliminary preparation and analysis for which specialization, time, and forces are needed, to a degree impossible for a scientist whose time is entirely occupied by his peculiar work. Since the analysis of the main scientific concepts is made by the philosophical work, a naturalist can and must (of course, looking at it critically) use it for his conclusions. He has no time to obtain it by himself

As to the study objects of philosophy and science, the frontier between them disappears when one deals with the general question of natural science. Sometimes one even calls these generalizing scientific ideas “philosophy of science”. I consider such understanding of the centennial objects of science to be incorrect, but the fact remains, and both philosopher and scientist embrace the general questions of natural science at the same time, while philosopher proceeds from the facts and generalizations of science, but not only from them.

As to a scientist, he must not leave the ground of the scientific facts (so far as it is possible). He must remain in these limits even when he accesses a scientific generalization.

84. Yet, this is not possible for him in all cases, and he does not always behave so.

A close connection between philosophy and science in the discussion of the general questions of science ("philosophy of science") is a fact to be reckoned with. This fact is tied up with the transcendence (by a naturalist, in his research work, in many cases, though he does not tell about it, nor does he even recognize it) of the exact, scientifically established facts and empirical generalizations. It is certain that in science (when it is built up in such manner), not more than a *part* of its assertions may be taken for granted and proven.

But this part covers *scientific facts,* millions of millions of them, and thus embraces and goes through a huge area of scientific knowledge. The number of the known facts grows incessantly, they become systematized and classified. These natural *facts* represent the main content of the scientific knowledge and scientific work.

Being correctly established, they are doubtless and generally recognized. Beside them one may identify the systems of the certain scientific facts whose main form is the *empirical generalizations.*

This is the main stock of science, scientific facts, their classifications and empirical generalizations which cannot raise doubts as to its certainty and *clearly distinguishes science from philosophy and religion.* Neither philosophy nor religion create such facts and generalizations.

85. Beside this main stock, science disposes of numerous logical constructions which connect scientific facts to one another and represent the historically transient, changing content of science: scientific theories, scientific hypotheses, working scientific hypotheses, conjectures, extrapolations, etc.; their certainty, in most cases, is low and they are subjected to great changes, bur their longevity in science may be sometimes very significant. They can last for centuries. They are in the process of a constant change and only differ essentially from the religious and philosophical ideas in that their *individual* character, the manifestation of *personality,* so peculiar and bright in philosophical, religious, and artistic constructions, recedes here to the background, perhaps due to their reference to the facts, Namely, the logical constructions of science are still based upon objective scientific facts, con

nected and reduced to them; in their generation, they are limited and defined by this peculiarity.

There had been, and there are, periods in the history of science when scientific logical constructions were advanced and when they covered their base, i.e. scientific facts, empirical generalizations, systems, and classifications.

Owing to this complexity of the science structure, it is difficult to understand its main structural character and its clear and radical distinction from philosophy.

During the course of time, a slow isolation (from the material of science) took place of the backbone of science which may be taken as generally recognized and proven for all; may not and must not raise doubts.

In different times and places, with variations for its different structural parts, science was becoming a special phenomenon separated from its historical roots: artistic inspiration[5], religious thought (magic, theology, etc.), philosophy. The history of this separation now may be only traced in its most general features.

86. The main features of the structure of science (the use of mathematics; logic; scientific apparatus) had developed, generally speaking, independently, and the historical course of their manifestation differed.

Mathematical sciences, whose exactness and obligatoriness do not raise any doubt became isolated first.

The contemporaries of the creation of mathematics did not recognize its importance, and its due influence in the cultural milieu of humanity (where mathematics became manifested) remained unconscious. As it is becoming manifested now and as it has been noted earlier (§ 42), we must attach to the ancient (2nd millennium B.C.) Chaldean mathematics far greater weight than it had been done before. Algebra and analysis became here so profound as they never were afterwards even in the ancient Greek mathematics. But in the Hellenistic epoch, they had been fully accessible for the scientists, for between 4th century B.C. and 6th century A.D., the Chaldean scientific work had evolved in a close contact with the Hellenic science. It seems that the geometrical

[5] This was very clearly recognized and many times formulated by Goethe (1749-1832) who often worked in science using his artistic inspiration.

thought of the Greeks, though incomparable in its power and profundity to anything that had existed before, still did not cover all the area of then existing mathematical knowledge[6].

The Hellenic mathematics has developed during almost a millennium. But in the Middle Ages this development ceased for almost another millennium, and revived approximately in the 16th century. After this time, mathematics developed gradually up to our epoch and revealed itself as new mathematics evolving rapidly and incessantly since 17th century.

During these three past centuries, a huge structure of mathematical sciences became created whose truth cannot raise any doubts and which is one of the highest manifestation of the human genius. In our times, science has almost reached the limits of its general obligatoriness and exactness. It revealed to itself the limits of its modern methodology. As it had been in the epoch of the Hellenistic science, the philosophical and scientific questions merged.

From the one hand, logic and axiomatic approaches touched the theoretical-cognitive problems which are yet unsolved and still may not be treated scientifically. From the other hand, we are approaching the purely scientific (and still inaccessible) solution of the problems of the real space-time with the help of higher geometry and analysis.

But letting alone these philosophical roots of scientific knowledge, and only basing on the vast area of the new mathematics and empirical generalizations, an explosion of scientific knowledge is evolving. We are now the witnesses of this explosion. Basing upon it, man transforms the biosphere. This is the

[6] Archaeological excavations and the successes of the history of the Ancient East and Egypt change our concepts. The historical criticism of the ancient Greek authors and their penetration into all material accessible to this critique make us to reject scepticism useful in its foundations but often leading to mistakes and fruitless in this area of knowledge. The history of technology shows us a great sum of scientific knowledge about which one did not even suspect 10 or 20 years ago. With reference to Chaldeans, it is important that the joint work of them and Hellenes took place during centuries (see in this connection : R. Archibald. *Babylonian Mathematics)I* Isis, 1936, vol. 26, pp. 63-81;

O.Neugerbauer. *Uber Vorgriechische Mathemathik* // Hamburger mathematishe Emzelsihriften, Hf. 8, Leipzig, 1929; Idem, *Vorlesungen uber Geschichte der Antiken Mathematischen Wissenschaften. Erster Band.* Vorgriechisihe Mathematik. Berlin, 1934. On the importance of O. Neugebauer's works see: R. Archibald. *Op.cit.,* pp. 65-66.

main condition of the creation of the noosphere.

87. Hardly much later with respect to the creations of the Hellenic (perhaps still earlier) and Hindu (§ 42) genius, another part of the exact knowledge has been evolving, equal in its obligatoriness to mathematical sciences. I mean the formation of sciences related to logic and methodology of thinking.

In the Hellenistic time, we see solid, though incomplete for our epoch, constructions embodied in Aristotle's logic[7]: "laws" which must be taken as obligatory.

In its main part, Aristotle's logic reveals the analytic power of his personality. Yet, a part of the logical discoveries that became manifested in this logic is tied up with Plato and was included into logic by Aristotle in its ready state from the current life of Athenian Plato's Academy. (Aristotle became a student in this Academy in 306 B.C.).

According to B. Jaeger's conception, acceptable (in my opinion) as a working hypothesis, Aristotle was the first Greek philosopher, "with whom we meet real abstraction. He owned all his thinking"[8]. Before the Aristotle's philosophy, the ontological logic alone existed. Aristotle divided logic into elements: word, or concept, and thing. Still it seems to me, that such notion in its last part ought to be changed under further work, for, in the Democritus' logic, the concept of thing had perhaps been more profoundly expressed than in the Aristotle's logic. In this relation, the logic of Democritus is nearer to the modern scientific logic of a naturalist than Aristotle's logic.

The logical analysis of the Hindus has achieved profound development approximately in the same ages when the Hellenic logical thought embraced reality scientifically. The profound Hindu logical systems had been formed independently of Greek thought: this fact seems to us all the more probable in the course of the deepening of our studies into these systems. At the same time during three hundred of years B.C. and in the first centuries

7. Perhaps, in the logic of the atomists (Democritus ?), still little studied, we have the beginning of that new understanding of logic which is becoming manifested in the course of development of the new science in the 20th century. See, for the Epicurean logic ... (so in the original text.—Edit. note).

8 W. Jaeger. *Aristotle.* (English edition: Oxford, 1934, pp. 369-370—Edit.

A. D. the cultural exchange between East and West was comprehensive and permanent. The exchange of the same nature and at an incomparably larger scale is observed only during the past 50 years.

Solely since the second half of the 19th century, logic took new direction, and along this line it is developing now. With acceleration. Beside Aristotle's logic basing upon the discourse and upon the laws of common sense, new sections of logic emerged, and in this new logic ("exact logic" of the Anglo-Saxes) logical science is synthesized with mathematics into new logic. These new trends in logic may be traced down to their generation in the 17th century, while the flourish of the new logic and the obstacles to its understanding which now are stimulating thought relate to the 20th century.

Nowadays, as we shall see, the development of biogeochemistry leads to the necessity for further explicating logical problems, and seem to me to form, in future, the logic of the noospheric phenomenon. I shall return to this later.

Logic is most closely tied up with philosophy and for long time has been identified with it, and so has been psychology. Logic has been mainly developed at the philosophical and not scientific base, which is one of the reasons for logic's retardation with reference to the requirements of sciences on nature, mainly descriptive natural sciences, first of all Earth sciences.

One part of logical constructions and ideas remains outside the scientific cycle and ought to be referred to philosophy.[9]

88. Much later the third foundation of science emerged, the *scientific apparatus of the facts,* which represents the system and classification of scientific facts whose accuracy reaches its limits, when they may be expressed in terms of the space-time, quantitatively and morphologically.

At this base, millions of millions scientific facts are being incessantly created, systematized, reduced to a form suitable for research work.

An unseen before *scientific apparatus of humanity,* ever growing and perfecting, is being created and increased constantly.

[9] Such are the "logic" of the philosophers like Hegel, or the psychological logic, not to speak about the irreal logic, like the "logic of angels" (in case they exist) by M. I. Karinskii. See the paper by M. I. Karinskii in the "Journal of the Department of People's Education".

This is the base of the new science in our time. Essentially it is the creation of the 17th-20th centuries, while separate attempts at building this base, and rather successful attempts, have been made even many centuries ago. But this fact gives no notion as to the real history of creating scientific apparatus in its current form.

Astronomy excluded, the apparatus that we dispose of only is the achievement of the past centuries.

Thus we still have no concept on the real history of the creation of scientific apparatus. No sufficient attention at all has been paid to this history, for the historians of science, strangely enough, only paid attention to the common questions of philosophical and generalizing character, but even for new time, not to the picture of the creation of the scientific apparatus. The contemporary scientific apparatus has almost as a whole been created during the past three centuries, but it has also included the fragment of the scientific apparatus of the past hardly known to us.

In reality, in the history of scientific thought, there had been several attempts at creating scientific apparatus. These attempts lasted for several generations. An authentic great scientific apparatus several times began to form consciousnessly, but afterwards it disappeared or ceased to develop in the stormy events of the political or social life. The causes of this had been complex but profound. Firstly, this was the periods of wars, cultural decline, internal struggle, and conquests within which no scientific work could find enough room for development. Secondly, there had been moral reasons, when man sought for support not in science but in philosophy or religion. These sentiments had been so deep that one could find neither working centers nor men for forming an apparatus.

But in addition to that, there had also been more realistic causes (be it permitted, to express it so). There had been neither book printing, nor any other powerful means for disseminating books, and scientific memory of the mankind concentrated in this scientific apparatus, could not be conserved to a sufficient degree in waiting for better times.

The movement that had begun in the 4th century B.C. is known to us with more certitude. Aristotle began his work at creating scientific apparatus in 335-334 B.C.. when he had return to Athens and founded a new higher school center independent of the

Academy of Plato, his teacher, who had died by that time. Lyceum was not a center for philosophical work alone but also for science which predominated. In Lyceum, Aristotle organized the concentration and study of the factual material of sciences, including the historical and state sciences: really he formed a scientific apparatus answering the late 4th century B.C. This was a scientific phenomenon of prime importance though it did not exert such influence that ought to be essentially brought to life by it.

After Theophrastes died in 288 B.C., Aristotle's manuscripts and library were only accessible to a few people, under the stormy atmosphere of the life of that epoch. In the last, they became conserved in a subterranean room and only about 100 B.C., i.e. 180 years later, bought by Apollikonos ofTheos, in damaged condition. Apollikonos put them into some order and made new copies of them. This happened about 100 B.C. When Sulla in 86 took possession of Athens, he transferred them to Rome (after Apollikonos' death). In Rome, Tyrannion of Amysos arranged them, and Andronikos of Rhodos introduced them back into literary use. This happened about 70 B.C.. This is the most plausible history on the fate of Aristotle's manuscripts[10]. At any rate, one sees from the said that the scientific apparatus as organized by Aristotle had not been accessible during more than 200 years, and therefore could not influence the scientific thought. In reality, this retardation introduced it into a new and alien scientific environment which could not estimate it in full degree.

89. Two phenomena ought to be noted in this context. First, the scientific apparatus began to be collected not by accident: it became a form of expression for the scientific work of one of the greatest scientific geniuses; it was created by a team fulfilling the task given to it by a single exclusive personality, to be executed under the management of the same personality[11]. Second,

[10] There had also been another tradition indicating that under Ptolemy Philadelphos (309-246 B.C.), the Alexandrian library possessed a complete collection of Aristotle's works. Concerning the current state of the question see: *Ueberwegs Grundriss der Geschichte der Philosophie* etc. (Tl. 1. *Die Philosophie des Altertums.* Herausgegeben von Dr. K. Praechter). Berlin, 1926, S. 365-366. (Compare: Kl. Usuner. *Schriften,* II, 307 foil.; Ill, 151 foil.)

[11] I proceed from the conclusions of W. Jaeger, taking also into account another living notions about this remarkable epoch in the history of the human thought. (Compare: W. Jaeger .*Aristotle.* Oxford, 1934).

this collecting occurred in the epoch when conditions existed under which the philosophical knowledge and understanding of the surrounding world was tied up with the rapidly developing technology against the background of an extraordinary enlargement of the culture world. This was a unique epoch (revived nowadays with more power) when the ancient civilizations of India and China, Egypt, Chaldea, and Greece began, after many century isolation, to communicate actively with relation to the ideas and everyday life.

Aristotle has been most closely connected with the non- Greek civilization of Macedonia whose language was distinct from Greek. Born in Thrace, being Greek in parentage and culture, he is an altogether extraordinary personality in world history. We saw his exclusive importance for liberating science from the depths of personality where it had been lost before him. Being equally great as a scientist and as a philosopher, and being during the later years of his life more a scientist than a philosopher, Aristotle was in science not only the creator of its logic and bright form, but also of its scientific apparatus. Against the historical background, the figure of Aristotle becomes clear to us in connection with the deepening of our knowledge in history of philosophy, when one began to try and distance from the understanding of this philosophy as a purely literary phenomenon, from narrow erudition, and to recreate Aristotle, Plato, and others (for whom it is possible) as living persons.

It seems to me that W. Jaeger (1912) has outlined the historical importance and historical work of these achievements of Aristotle very clearly and appropriately. He says: “For the people of our time, scientific study of the ‘subtleties’ long ceased to be unusual. We consider such study as a phenomenon imbued by the achievements, of the depth of experience: only under such study an authentic cognition of reality takes its way from experience. In our time, one needs a living and rarely found historical feeling to recognize the measure of strangeness and monstruosity of this way of study for an average educated Greek in the 4th century

B. C.; and to recognize the degree of the revolutionary innovation introduced then by Aristotle. Scientific thought ought to hammer, step by step, the methods now representing its most sure property and most usual tool. The technique of ordering the observation of the peculiarities has been, in its methodical realization, taken from the exact new medicine of the late 5th century B.C., and (in the 4th century B.C.) from the Eastern astronomy with its catalogues and chronicles continuous through centuries. Past writers on the philosophy of nature never exceeded the explanation by means of guessing about separate and remarkable phenomena. As it was said, "the Academy did not gave a collection of particularities but a logical classification of universal species and genera". "Aristotle was the first to analyze the sensual world as a substrate for the immaterial form. This task was a new one also as compared with the empiricism of the more ancient medicine and astronomy. He needed indescribable labor and patience to introduce his students to this new way of thought"[12].

Transferring these newly formed habitudes of exact factual knowledge into all areas of science of his time, Aristotle collected (in Lyceum, with the help of his students) an enormous material. Several examples may help one in understanding that. He edited critically 158 constitutions, organized team work (encyclopedic in its volume, unified in its form) on the history of all sciences of the Greek center of civilization. Essentially this was a history of the step-by-step development of human knowledge, edited and organized by one of the greatest creators of this knowledge and written in the critical epoch of its first (in the Greek world) dawn. The almost complete loss of these works remains irreplaceable. As one knows, Aristotle made the same job for his own research in the area of natural science: mineralogy, botany, and zoology. Not more than some miserable remnants of this work have lived through to our days in a distorted state. In the history of human thought, Aristotle is an unrepeatable phenomenon. "Though Aristotle's ideal was very high per se, still more remarkable is its realization in the mind of a single man. This is (and will remain) a psychological wonder never to be understood in more depth".[13]

The development of the scientific thought as distinct from the philosophical one in its Athenian center, Lyceum, stopped

12 *Ibid,* pp. 369-370.

13 *Ibid,* p. 405.

after the death of the second Successor of Aristotle, Strato from Lapmsakos, i. e. by the end of the 2nd century B.C. The questions of philosophy, religion, ethics occupied the minds of the thinking people and became predominating in Lyceum.

Still a center of scientific work was conserved in Alexandria being a spiritual continuation of the ideas of Aristotle in the late period of his life. A sharp distinction between scientific and philosophical work became manifested in Alexandria, both in the Museum and the Library, scientific thought became free, and the powerful and subtle technology of Ptolemaic epoch gave a base for experimental work. Here an unseen before scientific work in various areas began, against the background liberated from the pressure of philosophy: in medicine and natural sciences, in exact philology, mathematics, and logic. This development achieved maximum by the late 1st century B.C., perhaps to the early 1st century A.D. But there is no doubt that the science proceeded to evolve during several following centuries, perhaps not having manifested itself creatively. It is possible that scientific work in this center continued even several centuries after that and after the fall of the Museum and Library in Alexandria.

90. In reality, the main part of the scientific knowledge is its scientific apparatus, i.e. an incessant systematization and methodological processing (and the corresponding description, exact and full so far as it is possible) of all real phenomena and natural objects. Scientific apparatus must grow continuously with the course of time, it must change, it must (as the scientific memory of the mankind) mark and conserve everything that occurs in the surrounding world; it must go deeper and deeper into the past and the life of the planet; and first of all, it must register scientifically the changing picture of Cosmos, for us—the starry sky. Science only exists when this registering apparatus is functioning correctly; the power of the scientific knowledge depends upon the depth, completeness, and rate at which it reflects reality. Without scientific apparatus, science cannot exist, even if mathematics and logic exist. But also the growth of mathematics and logic can only take place when scientific apparatus is growing and all the time influencing them actively. For neither logic nor mathematics are immovable, they ought to reflect the movement of scientific

thought, and this movement manifests itself first of all, in the growth of scientific apparatus.

Strangely enough, this importance of scientific apparatus in the structure and history of scientific thought is not still taken into account, and there is no written history of its creation. At the same time, it is the most vulnerable part in the structure of scientific knowledge. It is enough to break the process of its formation for one or two generations and the scientific work of the humanity would cease or rather would manifest itself so feebly that its geological role at the general scale of humanity's life would be minimized. Not earlier than after centuries would the scientific apparatus be recreated. In the history of the mankind, which accounts for millions of years, the centuries, of course, do not have such importance which they have in our current life. But scientific apparatus is a manifestation of our current life, and its history (recognized by the mankind in its written monuments, chronicles, traditions, myths, religious and philosophical creativity) had began not more than ten thousand years ago. At this scale, a hundred of years is a great duration. The remnants of the material culture refer to much earlier times and prove the existence of a thinking man and his social life several hundreds of thousands of years ago (§ 21). But, as we have seen, science in the form of logic, mathematics, and scientific apparatus did not begin (as far as we know now) earlier than three or four thousands of years. We know the history of these three or four thousands of years exactly, to some degree, and the completeness of our knowledge is increasing in the measure to which we approach our time. Perhaps even before Aristotle, there had been an attempt at creating scientific apparatus. We cannot deny it, we ought to try and solve this question, but still we suppose that Aristotle was the first to begin working out scientific apparatus. Far more important is now the fact that this apparatus initiated by him came definitely to a stagnation (§ 68) and we now can trace exactly how it had been recreated in a far more powerful form.

91. The history of the fall of the Mediterranean civilization can now be traced down in the history of Western Europe and Western Asia with sufficient exactitude. At this scale, the collapse of scientific apparatus had been looked at by the contemporaries as a subtlety for they could see its real future felt by man not earlier

than in the 19th and 20th centuries.

We may trace the immanent collapse (never understood by the contemporaries) of the research center created by Aristotle that had existed in Athens. This center perished after Strato, in the mid- 3rd century B.C. The contemporaries could not estimate the significance of this event. They thought that this center continued to exist down to the times of Justinian (527-565 A.D.), that is, during many centuries more. In 529, Justinian closed the Higher School in Athens with its philosophical teaching, but then there had been no scientific work of Aristotelian type since long time in that school.

In the bloody turmoil events, scientific work in Alexandria became interrupted, though up to nowadays, we do not know how and when it occurred. Still just recently one came to know that this scientific center, perhaps also with diminished volume of research, persevered during several centuries more in the Arabian states, outside of Alexandria but in a continuity with it. It is very possible that its scientific significance had been greater than we estimate it to be, and this significance became expressed in the rise of scientific work in the Arabian states of the Middle Ages.

Still one hardly may doubt that in that epoch, the scientific apparatus had been weaker than in the epoch of the flourish of the Alexandria school.

But the states of Arabian culture could not conserve and develop steady research. The living scientific work in these states came to nothing during the bloody and destructive religious struggle between them and, from the one hand, Christianity, and from the other hand, the mighty invaders out of Middle Asia alien to both Islam and Christianity.

Scientific research found its place, owing to the complex conditions of political and social fife, at the Latin West, where scientific renaissance began in the 18th century and in the end led to the modem science.

92. Owing to the discovery of book printing in the late 15th century, a powerful possibility to be conserved for the future arose for scientific apparatus to a degree never possible before.

All subsequent centuries increased the possibilities for conservation and creation of scientific apparatus, and the new Western science powerfully grew in the 16th and 17th centuries. At that time, the most intense and profound was the development of scientific apparatus in the area of the philological, historical, and physical-chemical sciences. To a lesser degree, the scientific apparatus of natural sciences in a narrow sense and of biology, in wider sense of the word, became revealed and gathered together.

The apparatus of the physical-chemical sciences became most developed. It had been embraced by the scientific theory and could now be expressed in the form of the geometrical and numerical relations. Of an enormous importance were Newtonian generalizations having led to the creation of the mathematically expressed picture of world. This picture included neither life nor human sciences, i.e. did not cover the overwhelming part of the modem scientific apparatus. Still it permitted to foresee events, to predict them with an enormous exactitude, which had not been possible earlier in science to any considerable degree. This made an enormous expression and led to the wrong ideas on the nature of scientific apparatus and aims of the scientific research.

The modem foundations of the descriptive natural science were laid in the mid 17th century, while a definitive shift is tied up with the name of C. Linnaeus (1707—1778). The taxonomy in natural science became accessible, and the purpose of the exact and simple calculus of all natural bodies of nature was formulated. Linnaeus's first calculation of animals and plants gave their total number of several thousand species. Now this number approaches or exceeds a million.

But the most important thing is a mass movement initiated by Linnaeus: many thousand, probably hundreds of thousand people in his time began to study living nature, to define the species of animals and plants, exactly and systematically.

The 19th century, became a key epoch in the creation of scientific apparatus. Special organizations, partly international, came to life having as their purpose collecting, classification, and systematization of scientific facts, as well as intensification of the process of their accumulation and ordering. Simultaneously, all material was adjusted to the maximum growth through team work during generations. For that, special forms of organization were created.

They are numerous: institutes, laboratories, observatories, scientific expeditions, stations, files, herbaria, international and national science congresses and associations, sea expeditions and devices for scientific work, including ships, airplanes, stratostates; laboratories and stations in plants, intra-trust organizations, libraries, reference journals, tables of constants, geodetic and physical surveys, geological, topographical, soil, astronomical surveys, excavations, drilling, etc.

When it is possible, facts are expressed by number and measure, their accuracy is evaluated, if possible, numerically, or when it is needed, probabilistically: such is the necessary situation with relation to the physical, chemical, and astronomical data.

But not less exact are also the facts of biological and geological nature, through they cannot be completely expressed mathematically and numerically; also historical and humanitarian facts, including those from the history of philosophy, expressed solely through words and concepts but, as we shall see below, essentially distinct from the words and concepts of the philosophical and religious constructions.

This distinction covers all concepts and notions of scientific apparatus. It is tied up with the special logical character of the concepts and ideas of which scientific apparatus consists. In distinction from the huge number of concepts engaged in scientific theories and hypotheses, in religion and philosophy, the words and concepts of scientific apparatus are inevitably tied up with the natural bodies and natural phenomena; and the words related to these bodies and phenomena, to be understood properly, must in every generation be compared, through experience and observation, with reality that corresponds to them. Logical answering natural phenomena must inevitably be distinct from the logic of abstract concepts. We shall see that when I return to that below.

But we must dwell upon very widespread notions about the distinction between the material of scientific apparatus (1) expressed by the mathematical and numerical data and (2) inaccessible to such an expression. In the late 18th and early 19th centuries, many scientists used to think that science only then is fully developed when it covered by measures, by such or another form of mathematical symbols. There is no doubt that during the 19th and 20th centuries this trend had contributed to a gigantic progress of science in many areas. But in such form it evidently does not answer reality, for mathematical symbols are far from being able to cover all reality. In certain knowledge areas, this trend even leads not to deepening but to limitation of the power of science achievements.

The distinction between the content of science and the content of non-scientific knowledge, even philosophic alone, does not consist in mathematical aspect of science but in a special, strictly defined logical character of scientific concepts.

In science, we do not deal with absolute truths but with the unquestionably exact logical conclusions and with relative assertions whose correctness varies within definite limits. Within these limits, these assertions are logically equivalent to the logically unquestionable inferences of reason.

93. Thus we see that there exists a generally obligatory and scientifically true part of science. In this, science is clearly distinct from any other knowledge and spiritual manifestation of the mankind, and depends neither upon epoch, nor social and state structure, nor nationality and language, nor individual peculiarities.

This generally obligatory part of science includes:

(1) mathematical sciences in all their volume,

(2) almost entire domain of logical sciences,

(3) scientific facts in their system, their classification; and empirical generalizations made on the basis of these facts; i.e. *scientific apparatus* taken as a whole.

All these aspects of the scientific knowledge—unified science—are rapidly developing, and the area covered by them is ever increasing.

The new sciences are entirely permeated by these trends and are created being comprehensively armed by mathematics, logic, and scientific apparatus. Creation of the new science is the main feature and force of our epoch.

The living, dynamic process of such existence of science tying up past with present is spontaneously reflected in the vital milieu of the mankind and represents an ever increasing geological force transforming the biosphere into the noosphere. This is a natural process independent from any historical accidents.

Section three

NEW SCIENTIFIC KNOWLEDGE AND TRANSFORMATION OF THE BIOSPHERE INTO THE NOOSPHERE

CHAPTER VI

New problems of the 20th century: new science. Biogeochemistry and its inseparable connection with biosphere.

94. At our times, the framework of an *individual science* can not exactly define the area of the scientific thought of an explorer; can not exactly characterize his scientific work. Problems by which he is occupied more and more often exceed the limits of a separate, definite, established science. We do not specialize ourselves along the sciences, but along the problems.

Scientific thought of a scientist of our time is deepened (with a success and force unseen before) into new and immensely important areas that had not existed before or had been a monopoly of philosophy or religion. As compared with the 19th century, the horizons of scientific knowledge are being increased to an unprecedented degree.

Problems transcending the limits of a single science inevitably create new areas of knowledge, new sciences, whose number and quickness of emergence is ever increasing, which is characteristic of the scientific thought of the 20th century.

Sometimes, frequently enough, the name of a new discipline eventually reflects the complex nature of its convent, the connection between its scientific facts, methods, empirical generalizations, theories, and various elder scientific areas. For example, in the late 19th century, *physical chemistry* emerged whose problems are distinct from both physics and chemistry and require a peculiar synthesis of both scientific disciplines, with a prevailing accent upon one of them. The predominance of chemical notions and phenomena is often emphasized in the name of the discipline: chemistry, but not physics. In the 20th century, another science emerged in connection with it, and akin to it though clearly distinct from it:

chemical physics. The physical accent is manifested in its name. In both cases, in physical chemistry and chemical physics, the name of the discipline defines clearly and exactly its place in the system of scientific knowledge: in the area of chemical sciences, for one discipline and in the area of physical sciences, for another one.

Biogeochemistry, still younger and more complex scientific discipline which has emerged in the early 20th century, lacks this direct connection between the name and the nature of the discipline.

95. Also in biogeochemistry, how it is clear out of its name, chemical notions and chemical phenomena play leading part as compared with the geological and biological problems and phenomena which constitute its content and are reflected in its name.

But in accordance with the nature of *chemical objects* studied by it, biogeochemistry in its totality does not relate to only chemistry, but also to another enormous (and new, in process of being synthesized) knowledge area: *physics of atoms.* The name of biogeochemistry does not define exactly its position in the system of knowledge.

In this relation it its analogous to that physical-chemical discipline whose purpose is the study of atoms in their chemical manifestation and which is related either to physics of atoms, or to physical chemistry, or to crystallochemistry. This discipline evidently ought to be distinguished from physical chemistry and is equally close (or closer) to physics of atoms. It is not covered by physical chemistry for the properties of the atomic nucleus are most important for it. Methods of investigation differ essentially.

Besides, it covers the area of radiology, dealing with the decomposition of atoms and identifying isotopes. In contradistinction to chemistry, biogeochemistry proceeds rather from isotopes than from chemical elements.

96. Biogeochemistry in its totality is most closely tied up with a certain area of the planet, namely with one definite envelope of the earth: with the *biosphere*[1] and with its biological processes in their chemical (atomic) manifestation.

1 See: V. I. Vernadsky. *Biosphere.* L., 1926; id. *Problems of Biogeochemistry,* iss. 1, M.-L. 1935; id. *Biogeochemical Essays* (1922-1932). M.-L., 1940. Compare: *E. Le Roy. L’exigence idealisle et le fait de l'e’volution. Paris, 1927, pp. 102,* 111, 155, 175.

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

The area of life on the Earth had been named “biosphere” in 1975 by E. Suess (1831-1914). But as a special real phenomenon at our planet, as a natural body, biosphere had been identified much earlier, in the late 18th and the early 19th centuries.

But the biosphere as it is represented in biogeochemistry is only formally connected to Suess’ ideas. It really is the area of life at our planet, but this is not the single characteristic of it. Suess’ biosphere is the *face* of our planet, as he expressed figuratively, and the reflection of the planet into the outer cosmic space. It has a profound distinction from the biosphere as it is manifested from the study of biogeochemistry.

Biogeochemistry studies the biosphere in its *atomic structure* and lets alone (or at the second place) the *face* of the planet (das Antlitz), i.e. its surface geographic outlook and causes of its appearance studied by Suess.

In biogeochemistry, the biosphere is manifested as a peculiar Earth’s envelope clearly distinct from other envelopes at our planet. Biosphere is one of the concentric envelopes, embracing the entire Earth which closely adhere to one another and are called geospheres. The biosphere possesses a perfectly definite structure existing during billions of years. This structure is tied up with the active participation of life, is conditioned by life to a significant degree, and first of all is characterized by the dynamically mobile, stable, geologically durable equilibria which, in distinction from mechanical structures, are quantitatively traveling in certain limits with relation both to space and time.[2]

One may consider biogeochemistry as the *geochemistry of the biosphere,* a certain Earth’s envelope, namely the external

[2] See: V.I.Vernadskii. *Essays on Geochemistry.* Moscow, 1934, pp. 51-64.

envelope lying at the frontier of the cosmic space. But such definition of its area, though formally correct, essentially does not cover its overall content.

For introduction of *life* as a characteristic distinction of the phenomena studied in the biosphere lends to biogeochemistry very peculiar nature and enlarges the area of its competence, because of which it is suitable to identify biogeochemistry as a scientific discipline of its own. But the necessity of such division between biogeochemistry and geochemistry is also caused by other reasons than the problem of convenience for research.

This division is also necessitated by the essence of the question; by the distinction between phenomena of life and phenomena of inert matter[3].

Geochemistry covers the area of processes taking place in the lifeless inert matter, and only in the biosphere, life manifests itself brightly. But even here the *weight* of living matter is *not more than a few thousandths.* Life is absent outside of the biosphere.

Under energy aspect, life covers the biosphere and occupies in it the most important place, notwithstanding its very small relative mass, The biosphere itself occupies in the planet a peculiar place and is distinctly separated from other its areas being an area original in physical, chemical, geological, and biological aspects. One ought to take the biosphere into account as a special envelope of the planet, the biosphere is an appendage insignificant as to its weight. Being the face of the Earth, the biosphere is the only one place in the planet to which cosmic matter and energy penetrates.

Bearing all this in mind, one may appropriately identify biogeochemistry as an individual science and a peculiar branch of geochemistry.

Nevertheless, in its other main target, biogeochemistry extends beyond the limits of geochemistry. For only biogeochemistry approaches the main properties of life studying atomistically not solely the reflection of life in the biosphere, but also the reflection of atoms and their properties in the living organisms of the

[3] I shall address this problem again in the further account.

biosphere: in the aspect of this envelope inseparable from it.

A series of new problems (the biological ones permitting to apply experiment and not to limit oneself to scientific observation in the nature, i.e. in the biosphere) are only being elucidated in the biogeochemical field of research overstepping the limits of geochemistry and biogeochemistry, the latter being viewed upon as geochemistry of the biosphere.

This makes separation of biogeochemistry from geochemistry as a science of its own still more necessary.

97. More that this: as we shall see, geologically, we evidence now the identification of Noosphere[4] the *reign of the reason* in the biosphere which is also changing the face and structure of the biosphere.

Tying up together the life phenomena in their atomistic aspect and taking into account the fact that these phenomena are placed in the biosphere, i.e. in the environment of a definite structure only relatively changing with geological time, and that they are genetically connected with it in an inseparable way—taking all this into consideration, one must inevitably admit a closest contact between biogeochemistry and science not only dealing with life but also with man: *human sciences.*

Already proceeding from this single fact, we must connect biogeochemistry with the area of human sciences and not uniquely of biological sciences.

Scientific thought is a part of a structure (organization) of the biosphere, and the manifestations of it, the origin of life in the evolutionary process is an event of greatest importance in the history of the biosphere, in the history of the planet (§ 13). In classification of science, the biosphere must be taken into consideration as a factor of the utmost significance, which has been never done, so far as I know. Sciences of phenomena and natural bodies of the biosphere are peculiar.

98. With the approach to man in the scientific cognition of reality, the volume, diversity, and profundity of scientific knowledge inevitably increase. The number of *human sciences* increase

[4] The term “noosphere” and the corresponding concept have been coined by E. Le Roy (see his book *Les origines humaines et revolution de Vint ellegence*. Paris, 1928, p. 46).

es constantly. Theoretically speaking, this number is endless, for science is a creation of man, of his scientific potential and his research work. There are no limits for scientific search, as there is no limit for the endless forms of revelation of a living personality, especially a human personality, and all these revelations are eventual objects of scientific search, so creating a variety of peculiar individual sciences.

Man lives in the biosphere, is inseparable from it. It is *only the biosphere* that can be investigated by him immediately, by all his organs of sense: only the biosphere and its objects can be felt.

Beyond the limits of the biosphere, man can only penetrate by constructions of his reason, proceeding from relatively few categories of numerous facts which he can obtain in the biosphere by visual investigation of sky and by research into reflections (also in the biosphere) of cosmic rays or cosmic extraterrestrial substance delivered into the biosphere.

It is evident that scientific knowledge of Cosmos available only in this way never may be even compared in diversity and profundity with the scientific problems and their disciplines which answer the biospheric objects and their scientific cognition.

The biospheric objects can be embraced by all senses of man immediately, and at the same time the reason that builds science is materially and energetically inseparable from the biosphere, being one of the objects in it. Man introduces in scientific constructions the experience of a human personality which is mightier than the feelings excited in man by the immediately accessible to him purely visual picture of starry sky and planets. For studying heavenly bodies and Cosmos built up from them, man only may use their radiation, their physiological action upon human eye, their physical-chemical analysis, and their study by means of mathematical thought. Only comparatively very small are energetic and material manifestations of cosmic bodies, such as cosmic dust, cosmic gases, or meteorites that become terrestrial objects when getting into the biosphere. In that they become accessible (to a maximum degree) to human thinking, while playing only an insignificant part in the picture of human reality and in the experience of a human personality.

In our scientific apparatus, phenomena tied up with the cosmic space outside our planet correspond perhaps more than to hundreds of million of exact data whose expanse is rapidly growing.

However, the number of such scientifically established facts is negligible as compared with the objects that can be discovered in the biosphere by science and that can cause a diverse influence upon human personality whose part they can eventually become.

Our knowledge of cosmos is sharply distinct from the knowledge inherent in sciences built up upon the objects that belong to the biosphere. The knowledge of cosmos does not give us more than the general outlines of its structure.

99. However, also in an opposite direction, not upwards proceeding from the biosphere, but downwards, into the interior of the planet, we meet similar conditions: natural limitations of exact knowledge owing to impossibility of an immediate study of this environment, for man only can conjecture about its nature and structure from the laws of its reason and the echoes of the phenomena occurring in it and perceived by his senses, or eventually reduced to them by his tools.

Nevertheless, here man is deprived of the main sense which gives him a possibility to penetrate far into the outer space: he is deprived of the sense of *vision* which is so closely and inseparably connected with the brain and permits to recreate, from all visible by man, the *reality,* the unique object of scientific knowledge and, first of all, of the sciences dealing with the biosphere[5] (§ 32).

However, on the other hand, human cognition of the biospheric part of the planet is more diverse, for the man can: (1) to deepen step by step, with the course of time, the area immediately accessible to his senses, *and the limit of this deepening far*

[5] In the realm of geological (and biological) sciences, the researcher might let. alone the ideas on reality formed by cognition theory and urgently taken into consideration, for example, by physics. In science of this type, there is no notion deduced from scientific theory, like those we have in the realm of many physical phenomena and suitable for analyzing them with physical techniques, with some efficiency. But also for physics, this philosophical approach only has an essentially secondary meaning.

exceeds the boundaries of the biospere. With every decade, man advances in the bowels of the earth with acceleration, and he can

(2) connect the depths of the planet (the Earth's crust beneath the biosphere and, perhaps, the nearest areas beyond the crust materially and inseparably tied up with biosphere) with that diverse and very significant for science factual data which are derived from the sciences studying the biosphere. Owing to that, in this area of reality, during few centuries (with scientific exactitude—since the 17th century[6]), we achieved knowledge entirely comparable with the knowledge of Cosmos. In this area, the forecast for further study is more favorable than in the area of the scientific modeling of Cosmos.

This is tied up with the fact that here we do not leave the limits of a natural objective body—the planet on which we live. Thus we may, proceeding from the study of the biosphere, not only obtain the general outlines of the phenomenon, but also receive, to a certain degree, a multicolor picture of reality.[7]

CHAPTER VII

Structure of scientific knowledge as a manifestation of the noosphere—a new geological state of the biosphere caused by this knowledge. The historical course of the planetary manifestation of Homo sapiens through the creation (by him) of a new form of the cultural biogeochemical energy and of the noosphere which is tied up with this energy.

100. Sciences on the biosphere and its components, i.e. all human sciences, without any exception; natural sciences in the proper sense of the word: botany, zoology, geology, miner

[6] It is only in the 20th century, before our eyes, the drilling has reached and given matter from the depths exceeding the level of the geoid. Earlier, these depths have been inaccessible owing to the natural variation of this level. Significant advances to the deep (in the mines) began in the 17th century. The ideas by Parsons (1935) about maximum drilling now became true.

[7] Like the biosphere, which is one of the envelopes of the Earth's crust, the depths beyond the crust represent to us several regular concentric envelopes, each of them being a natural body. See: V. I. Vernadsky. *Ocherki geokhimii.* Moscow, 1934, pp. 51-64.

alogy, etc.; all technological sciences (applied sciences in broader sense)—are the areas of knowledge which are to a maximum degree accessible for the scientific thinking of man. Here, billions of scientific facts become concentrated which are being continuously established and systematized by science and which are a result of the organized scientific labor. These facts have been gradually accumulated from generation to generation, rapidly and consciously, beginning from the 15-17th centuries.

In particular, the scientific disciplines studying the structure of the instruments of scientific cognition are inseparably tied up with the biosphere and may be scientifically viewed upon as a geological agent, as a manifestation of its organized state. These disciplines are the sciences on the "spiritual" creativity of a human personality in its social environment, on brain and senses, on problem of psychology or logic. They necessitate the search for the main laws of human scientific cognition as the force which has transformed (during our geological epoch) the biosphere ruled by man into a new natural body, with relation to its geological and biological processes. This new natural body is the new state of the biosphere, the noosphere[1], and will be considered further on.

The creation of noosphere in the history of our planet began (intensely, at the historic time scale) several tens of thousand years ago. It was an event of the utmost importance in the history of our planet, and this event had been tied up, first of all and evidently, not by accidence, with the growth of the sciences on the biosphere[2].

Therefore one may say that the biosphere is the main area of the scientific knowledge, although it is only now that we approach its scientific identification within the frame of the reality that surround us.

[1] *E. Le Roy. Les origines humaines et I 'evolution de Iintelligence. III. La noosphere et I hominisation. Paris, 1928, pp. 37-57.*

[2] I shall return to this process below. Here, I would note a thought of Le Roy (1928): "Two great facts, before which all other ones seem to be almost insignificant, dominate the past history of the Earth: the vitalization of matter, and then the hominisation of life". The first fact is hypothetical, but the beginning of the second one may be clearly seen by us.

101. It is clear from the above said that the biosphere corresponds to the nature in its usual sense, in particular to the nature of naturalists (in their thought and in most philosophical discourses in the cases when Cosmos as a whole was not touched upon but the thought was restricted to the Earth).

However, this nature is neither amorphous nor formless as this has been thought for centuries, but has a definite, very strictly defined *structure*[3] which as such must be reflected and taken into consideration in all conclusions and inferences tied up with the "nature".

In scientific search, it is especially important not to forget about this structure and to take it into consideration, for, unconsciously, man and thinker are suppressed by the greatness of "nature" and its domination over human personality to which it is opposed.

However, life in all its manifestations, including the manifestations of a human personality, changes the biosphere sharply to such a degree that neither the set of living individuals nor, in several problems the unified human "personality in the noosphere" can be omitted without attention in the biosphere.

102. The living nature is the main feature of the manifestation of the biosphere, and owing to this, this clearly distinguishes it from other Earth's envelopes. First and foremost, the structure of the biosphere is characterized by life.

As we shall see in § 135, there is an impassable abyss in relations between the physical-geometrical properties of living organisms (in the biosphere, they reveal themselves as their sets, as the living substance) and those of the inert matter, which includes an overwhelming part of the biosphere, with reference to the weight and number of atoms. The living substance is the carrier and generator of free energy which does not exist in any of the

[3] This "structure" is very peculiar. It is neither a mechanism nor anything immovable. It is a dynamic equilibrium, eternally changing and moving, in no moment identical and never returning to its past image. Something most close to it is a living organism which is still distinct from it in the physical-geometrical state of its space. The biospheric space is heterogeneous with relation to physics and geometry. I think that this structure may be conveniently defined by a special notion—"organized state". See § 4. Compare: V. I. Vernadsky. *Problems of Biogeochemistry. Iss. I. The Importance of Biogeochemistry for the Study of the Biosphere.* L., 1934.

Earth's envelope at such scale. This free energy, *biogeochemical energy*[4], embraces all the biosphere and, in general features, determines all its history. The biogeochemical energy evokes and sharply changes (as to its intensity) the migration of chemical elements which build up the biosphere; and defines its geological structure.

During the past ten thousand years, a new form of this energy arises for the first time, and its importance rapidly increases. This new form of energy tied up with the activity of human societies of the genus *Homo* and similar genera conserves the manifestations of the simple biogeochemical energy but at the same time causes new migration types of chemical elements. These new migration types in their diversity and strength leave far behind the usual biogeochemical energy of the living substance of the planet.

This new form of biogeochemical energy, which may be called the *energy of human culture* or cultural biogeochemical energy, is the form of biogeochemical energy, which is now creating the noosphere. Later on I shall return to a more detailed exposition of our knowledge of the noosphere and to the analysis of this knowledge. However now I ought to elucidate shortly its appearance at our planet.

This form of biogeochemical energy is not only peculiar to *Homo sapiens,* but also to all living organisms.[5] Yet in them, this energy is insignificant as compared with the usual biogeochemical energy, and hardly manifests itself in the balance of

[4] The concept of the biogeochemical energy had been introduced by me in 1925 in a still unpublished report to L. Rosental's foundation in Paris, which gave me a possibility to work quietly during two years. In press, this concept may be found in my articles and books: (1) *Biosphere.* L., 1926, pp. 30 48; (2) *Etudes bio- geochimiques, I. Sur la vitesse de la transmission de vie duns la biosphere.* Izvestiia AN, 6 ser., 1926, vol. 20, no. 9, pp.727-744; (3) *Etudes biogeochimique, 2, La vitesse maximum de la transmission de la vie dans la biosphere.* Izvestiia AN, 6 ser., vol. 21, no. 3-4, pp. 241-254; (4) *On the reproduction of the organisms and its importance in the mechanism of the biosphere. Articles 1-2,* Izvestiia AN, 6 ser., 1926, vol. 20, no. 9, pp. 697-726; no. 12; pp. 1053-1060; (5) *Sur la multiplication des organimes et son role dans le mecanisme de la biosphere, 1-2 p.* Revue generale des sciences pures et appliques. Paris, 1926, vol. 37, no. 23, pp. 661-668, 700-708; (6) *Bacteriophague and the rate of transmission of life in the biosphere,* Priroda (Nature), 1927, no. 6, pp. 433-446.

[5] *V. I. Vernadsky. Biosphere, pp. 30 t8; idem, On the reproduction of organisms and its importance in the mechanism of the biosphere. Op. cit. no. 9, pp. 697-726; no. 12, pp. 1053-1060.*

nature; and even when it does, the results may only be seen at the geological time scale. This form of biogeochemical energy is tied up with the psychical activity of the organisms, with the development of the brain in the higher manifestations of life, and is reflected in the process of the transition of the biosphere into the noosphere only taking place with the appearance of reason.

The reason had been becoming in being in the ancestors of man perhaps during several hundred of millions years, but this process came to its expression as a geological force only in our times, when *Homo sapiens* embraced all the biosphere by his life and cultural work.

103. The biogeochemical energy of living substance is first of all defined by the reproduction of organisms, by their constant, trend at achieving the minimum of free energy determined by the energetic features of the planet: thus it is defined by the main laws of thermodynamics which correspond to the existence and steady state of the planet.

This energy is expressed in the breath and nutrition of the organisms and can be described by the "nature laws" still not formulated mathematically although the purpose to seek for such formulae had been clearly advanced as early as in 1782 by C. Wolf, in the then St. Petersburg Academy of Sciences.

It is evident that this biogeochemical energy, this form of it, is also characteristic of *Homo sapiens.* This energy is his *feature of species*[6] (like it is in all other organisms) and seems to us to be unchangeable during geological time. In other organisms, there is also another form of "cultural" biogeochemical energy which is unchangeable or hardly changeable. This other form appears in the everyday life or technical conditions of the life of the organisms: in their motions, in habitudes, in building of domiciles, in displacement of the surrounding matter, etc. As I had indicated, this energy is only an insignificant part of the total biogeochemical energy of these organisms. In the man, this form of the biogeochemical energy tied up with the reason, increases and grows with time and rapidly advances to the foreground. This

[6] On feature of species see: V. I. Vernadsky. *Considerations generates sur I'e- tude de la composition chimique de la matiere vivante.* Works of the Biochemical laboratory. Vol. 1, 1930. pp. 5-32.

growth is possibly connected with the growth of the reason itself (a process that seems to be very slow, if it does exist at all), but mainly with the precision and deepening of the use of reason which is tied up with the conscious change of the social environment, in particular, with the growth of scientific knowledge.

I shall proceed from the fact that, during hundreds of thousand years, the skeletons of *Homo sapiens,* including his cranes, do not give any base for considering them as belonging to some other species of man. This is only possible under the condition that the brain of a paleolithic man had no essential structural distinctions from the brain of a contemporary man. At the same time one may have no doubt that the reason of a paleolithic man cannot stand against the reason of a contemporary man. It follows that the reason is a complex social structure built up (both, for a man of our times and for a paleolithic man) upon one and the same nervous substrate, but under different social environment as synthesized in time, essentially in the space-time.

The change in this environment is the main agent which had in the end led to the transition from the biosphere to the noosphere. An evident and foremost cause of this transition was the forming and growth of the scientific understanding of the surrounding world.

104. The forming of the cultural biogeochemical energy upon our planet is the main event in its geological history. This event has been prepared during all the geological time.

The main and decisive process for this event has been the maximum manifestation of human reason. Yet, this very manifestation is inseparably tied up with the biogeochemical energy of the living substance.

Life ties up together all the atomic migrations of the inert matter of the biosphere by the migrations of the atoms in the life process.

Organisms are only alive to the moment when the matter and energy metabolism between them and the biosphere that surrounds them does not cease[7]. The grandiose and strictly definitive circular processes of atomic migration are elucidated in the biosphere, and liv

[7] For the latent forms of life, one may still not keep for proven the complete absence of the exchange with their environment. This exchange is very slow, but perhaps really in some cases the migration of atoms is absent and can be only noticed during geological time.

ing organisms are included into these processes as their regular, inseparable, often main part. These processes are unchangeable during geological time and, for example, the migration of the magnesium atoms to the molecules of chlorophyll continues incessantly at least during two billions years through an endless number of generations of green organisms, and all these generations are genetically connected with one another. Already owing to the atomic migrations, the living organisms are closely and inseparably tied up with the biosphere being a regular part of its structure.

One should not forget it under scientific study of life and under scientific reflection on all its manifestations in the "nature". We cannot miss the fact that a continuous tie (material and energetic connection between a living organism and the biosphere, the connection perfectly definite in its character, "geologically eternal" and scientifically expressible to the degree of exactitude) is always present under any our scientific approach to the living and must be reflected in all our logical conclusions and inferences about the living.

Beginning our studies of the geochemistry of the biosphere, we ought to estimate first of all and exactly the logical sense of the said connection between the organism and the biosphere. This connection is a necessary part of all our conjectures tied up with life. It does not depend upon our will and cannot be excluded from our experience and observation. We always must take it into consideration as some fundamental characteristic of the living.

In this way, the biosphere ought to be reflected in all our *scientific judgments,* without any exception. It must be present in every scientific experiment and observation, as well as in any reflection of human personality, in any speculation which is an unavoidable thing for a human personality, even in its thought.

The reason can be manifested in such a way to a maximum degree only under the maximum development of the main form of the biogeochemical energy of man, i.e. when the man became reproducing himself to a maximum degree.

105. A potential possibility of the occupation of all the surface of the planet by the reproduction of a single organism or species is inherent in all organisms, for in them all, the law of reproduction may be, formulated in a similar form—as the law of

geometric progression. I have noted the cardinal importance of this phenomenon for biogeochemistry long ago[8] and I shall return to it again in the due place of this book.

As it seems, the phenomenon of the occupation of all the surface of the planet by a single species is widely developed in the aquatic life, in the microscopic plankton of lakes and rivers, as well as in some forms (in essence, also aquatic ones) of microbes, living in the surface cover of the Earth and disseminating through the troposphere. For larger organisms, we observe this phenomenon to almost complete degree in some plants.

For man, this trend begins to become manifested in our time. In 20th century, it covers all the land and all the seas. Owing to the successes of communication, man can support inseparable relations with the entire world and never be alone, never be lost among the magnitude of the Earth's nature.

Now the number of people on the Earth has reached a quantity unseen before, approaching two billions, notwithstanding that the murders (wars) and hunger (under-nourishment) to which hundreds of millions people are constantly subjected weaken the course of the process extremely. It is a question of a short (from geological viewpoint) time span, hardly more than several hundred years, to cease these survivals of vandalism. This can be done easily even now. The possibilities for this are already in the hands of the man, and the reason will inevitably go this way, for it answers the natural trend of the geological process, especially as the opportunities for action along this line are rapidly and almost spontaneously increasing. The real significance of popular masses who suffer most from this trend is growing irrepressibly.

The number of people inhabiting our planet began increasing about 15-20 thousand years ago when man, as a result of the discovery of agriculture, became less dependent upon the food shortage. It seems that at that epoch, approximately 10-8 thousand years ago, the first outburst of the reproduction of humanity occurred[9]. J. F. Nikolai in 1918-1919[10] tried to estimate quantitatively the process of the real

[0] *See: V. I. Vernadsky. Biosphere, pp. 37-38. Idem, Etudes biogeochimiques. 1. Sur la vittese de la transmission de la vie dane biosphere. Op. cit., no. 9, pp. 121 - 744; idem, Biogeochemical essays, M. L., 1940, pp. 59-83.*

[9] V. J. Childe. *Man Makes Himself.* London, 1937, pp. 78-79.

[10] *J. F. Nikolai. Die Biologie des Krieges. 1. Betrachtungen eines Naturfordchers den Deutschen zur Besinnung, Band 1, Zurich, 1919, S. 54.*

reproduction of man, the development of agriculture, and the colonization of the planet by man. After his calculations, taking into account all the surface of the Earth, there is 11.4 man per square kilometer, which gives 210‘ % of the possible settlement. Considering the energy supplied by the Sun, agriculture gives a possibility to feed
150 people per square kilometer, which gives for all Earth 22.5-10 individuals, i.e. 22-24 times more than the present population of the Earth.[11] However it is not by agricultural labor alone that man obtains energy for his feeding and living. Having taken into consideration this possibility, Nikolai conjectured that during the historical epoch (which has began in our days) of the use of the new energy sources,
the Earth might be populated by 3 1 0 ' of people, which is by tens of million greater than the number of the contemporary mankind. At the present moment, after more than 20 years after Nikolai's calculations, these quantities ought to be significantly increased, for man really can now use the energy sources about which Nicolai did not think in 1917-1919: the energy sources tied up with the atomic nucleus. Now we must say in a more simple way that the energy source, mastered by the reason in the energetic epoch of the life of humanity which we now enter, is practically endless. From this, it is clear that the cultural biogeochemical energy (§ 17) also is inexhaustible. After Nikolai's calculations, in his time, machines increased the power of man more than tenfold. Now we cannot give a more exact calculation, but recent computations of the American Geological Committee indicate that the water power used in the world has reached 60 millions of horse powers by the end of 1936; during 16 years, it increased by 160 per cent, mainly in North America.[12] Already owing to that, one ought to augment the Nicolai's results more than by one and a half.

In essence, all these numerical calculations about future have no importance, for our knowledge about the energy accessible to man is so to say rudimentary. Of course, the energy accessible to man is not an endless quantity for it is defined by the size of the biosphere. This also defines the limit of the cultural biogeochemical energy.

1 * J. F. Nikolai. *Op. cit.,* S. 60, note 31.

12 *Water Power of the World (News and Views)* Nature, 1938, vol. 141, no. 3557, p. 31

We shall see in § 138 that there is also a limit of the main biogeochemical energy of the mankind, i.e. of the rate of the spreading of life; a limit of the reproduction of man.

The rate of settlement—the quantity *V* essentially considered by Nicolai—is based upon the really observed man's colonization of the planet, under evidently unfavorable for his life conditions. Beside that, we shall further see that there exist some biospheric phenomena unknown to us and leading to a stationary maximum number of individuals who can exist over an area of 1 hectare under given biocenotic conditions.

106. The abundance of human population at our planet may only be calculated with some exactness beginning from the early 19th century, and under this calculation, the percentage of a possible error is big. During past 137 years, our knowledge increased greatly but still cannot achieve the exactitude now required by science. For more distant times, the numbers are but very relative, though they help to understand the process which took place.

Under this aspect, the following data may be of importance for us.

In the Paleolithic period, the numbers of people probably achieved few millions. Let us admit that initially there was one family, though an opposite opinion is also possible.[13]

In the Neolithic period, there were probably several tens of million people. Perhaps one may assume that even in the historic time this number for a long time did not reach one hundred million or a little more.[14]

For 1919, J. F. Nikolai conjectured the annual increase in the human population of the planet in 12 millions people, i.e. 30 thousand people per day. After the critical review of Kulischers (1932)[15], in 1800, the world's population reached 850 millions people, after A. Fischer, it was 775 millions people. The numbers of the white race may be assumed for the year 1000 to be 30 millions, for 1800—210

[13] See: E. Le Roy, *op.cit.*

[14] B.RWeinberg in his scientific fantasy *Twenty thousand years of the works on the annihilation of the oceans: An essay on the history of the mankindfrom primitive state to the year 2230* (Sibirskaya priroda, Omsk, 1922, no. 2, p.21) assumes for the beginning of our era a population of 80 million people.

[15] A. und E. Kulisaher. *Kriegs—und Wanderzuge.* Weltgerchichte als Volkerbewegung. Berlin - Leipzig, 1932, S. 135.

millions, for 1915—645 millions. After Kulischers, in 1906, all the humanity numbered about 1700 millions, but after A. Hettner (1929)[16]—1564 millions, and after himself (1925)—1856 millions.

Evidently at our time this number has reached about two billions people, perhaps a few more or less. The population of our country (about 160 millions) makes up about 8% of the world population. The total world population grows quickly and perhaps the percentage of our population in the world is relatively growing, for the increase in population in our country is greater than the average increase in all the mankind. In general, we ought to wait for a significant excess over two billions people towards the end of this century.

107. The reproduction of the organisms, i.e. the manifestation of the biogeochemical energy of the first type, without which there is no life, is inseparable from man. However, since the very moment of his self-identification from the total mass of life on the planet, man possessed tools (be it only rude tools) which permitted him to increase his muscle strength and became the first revelation of contemporary machines distinguishing man among other living organisms. The energy which fed them still was produced by the nourishment and respiration of the human organism itself. Probably already several hundred thousand years ago, the genus *Homo* and his ancestors possessed wooden, bone, and stone implements. Slowly, during a long series of generations, an ability to prepare and use these tools had been worked out. The *skill—reason* in its first manifestation became perfected.

These tools have been already observed for the early Paleolithic period, 250-500 thousand years ago.

At that time, a significant part of the biosphere was passing through its critical stage. To all appearance, already in the Late Pliocene, a sharp change in the water and heat balance of the biosphere occurred, the *glacial period* began and continued developing. Apparently we still live in the fading of its last manifestation: whether temporary or final, this is unknown. In this half a million years, we see abrupt fluctuations of climate; relatively warm periods of tens and hundreds years both in the Northern and Southern hemispheres gave way to the periods when masses of ice moved

[16] A.Hettner. *Der Jang der Kultur uber die Erde.* 2 te, umgearbeitete und erw. Aufl. Leipzig-Berlin, 1929. S. 196.

slowly, judging from historical scale, and achieved a thickness of a kilometer, for example, at the outskirts of Moscow. In the Leningrad region, they disappeared about seven thousand years ago[17], while Greenland and Antarctic regions still remain occupied by them. Apparently, *Homo sapiens* or his immediate ancestors were formed a short time before the beginning of the glacial period or in one of its warm intervals. Man lived through the severity of the cold of that time. This became possible owing to the great Paleolithic discovery of that time, the mastering of fire.

This discovery was made in a single or perhaps a few places, and disseminated slowly over the population of the Earth. Apparently, we deal here with a process common for great discoveries: they are rather manifestations of separate human individualities than of the mass human activity smoothing away and bettering particularities. For more recent times and in very many cases, we are able to trace this exactly, as it will be shown later, in § 134.

The discovery of fire became the first case when a living organism came to rule one of the forces of nature and became its master.[18]

Beyond all question, this discovery, as we see now, is a base of all the subsequent growth of mankind as well as of our present strength.

Nevertheless, this growth was extremely slow, and it is difficult to us to imagine conditions under which it only could occur. Fire was already known to the generic ancestors or predecessors of that Hominidae species which is now building up the noosphere. The recent discovery in China shows us the remnants of the Sinanthropus culture testifying to the wide use of fire by the Sinanthropus probably long before the last glacial period in Europe, several hundred thousand years before our time. We have now no reliable data about how Sinanthropus made this discovery. He was endowed by reason, had rude tools, used speech, exercised the interment cult. He already was a man, although many his morphological features were alien to us. One cannot exclude that Sinanthropus is one of the ancestors of

[17] Now we know that in the environs of Leningrad the ice has disappeared about 12 thousand years ago.

[18] V. G. Childe. *Man Makes Himself.* London, 1937, p. 56. Compare: J.G.Frazen. *Myths of the Origin of Fire.* London, 1930.

the contemporary human population of China.[19]

108. The discovery of fire is especially striking as before man, any appearance of fire and light in the biosphere was a relatively rare phenomenon and was manifested mainly at a large-scale, in the forms of cold light, such as the luminescence of heaven, Aurora Borealis, quiet electrical dischaxges, stars and planets, gleaming clouds. Only the Sun, the source of life, was a bright manifestation of light and heat, simultaneously illuminating and warming the dark planet.

A living organism have long ago elaborated the manifestation of cold light. It was expressed in such major phenomena as marine luminescence, usually covering hundreds of thousand square kilometers, or the fluorescence of the sea depths. It is only now that the importance of the latter phenomenon becomes clear to us. Fire accompanied by a high temperature occurred in the local phenomena rarely covering much space, for example, in volcanic eruptions.

However, these grandiose, at a human scale, phenomena, evidently owing to their destructive force, in no case could favor the discovery of fire. Man ought to seek for it in the manifestations of nature more close to him and less terrific and dangerous than volcanic eruptions, which even now exceed the forces of modem man. It only nowadays, that we approach their real use, under conditions that had been inaccessible and unthinkable for the Paleolithic man.[20]

He had to seek for the phenomena giving heat and fire in the surrounding life. In the places of his settlement in the forests, steppes,

See on the technique of Sinanthropus and fire by him: D. Bogaevskii. *Technique of the primitive communist society,* History of technology, vol. 1, pt. 1, M.-L., 1936, pp. 26-27 (In Russian). Pithecanthropus, who lived earlier, in the very beginning of the Pleistocene, hardly more than 550 thousand years ago, also possessed fire. Compare: D. Bogaevskii, *op. cit.,* pp. 11, 67. One cannot take the use of fire by Pithecanthropus for granted, but it is highly probable.

[20] Only in the 20th century in Larderello, with the help of drilling, after the initiative of Le Conte, man obtained superheated vapor (140° C) as a source of power. Still later, in Soffioni (New Mexico) and Sonoma, this method had been further developed. Parsons, before his death, worked on a practical design to get, with the help of deep drilling, an inexhaustible (from a human viewpoint) source of energy from the inner heat of the Earth’s crust. An analogous (to a certain degree) attempt at obtaining energy from the cold depths of the ocean was contemplated by a French academician Claude, but he did not manage to realize it because of criminal and insolent counteraction. In these phenomena, we undoubtedly have a practically inexhaustible force in the hands of man.

among living nature with which he lived in a lively, long forgotten for us intercourse. Here he could meet fire and heating in a safe for him form, in a series of usual phenomena. These phenomena were on the one hand, fires (conflagrations), the combustion of the living and dead life matter. Just these sources of fire were used by a Paleolithic man.

He burned trees, plants, bones: the same material that gave fire around him apart from his will. Before man, this fire had been caused by two clearly distinct causes. On the one hand, the thunderstorm discharges caused forest fires or kindled dry grass. Also now, man suffers from these causes of fire. The natural conditions in the glacial period, especially in the interglacial eras, possibly gave even more favorable conditions for thunderstorm phenomena. However there was also another cause having formed a fire independent of man.

This was the activity of lower organisms leading to the fires of dry steppes[21], to the burning of the coal layers which lasted for several human generations and gave an appropriate possibility to obtain fire. This activity led also to the combustion of the peatbogs. We have immediate indications in such coal fires in Altai, in Kuznetsk basin, where they took place in the Pliocene and post-Pliocene, and where they are to be reckoned with even now. The causes of these fires still remain unknown exactly, but all indicates that we hardly deal here with the phenomenon of a purely chemical process of spontaneous combustion, i.e. with an intense oxidation of fragmented coal by the oxygen of the air or with the spontaneous combustion of coal under the action of heat appearing during the oxidation of the iron sulfides contained in coal.[22]

[21] One sometimes denies the spontaneous combustion of dry grass in the steppes, pampas, and forests. Nowadays, almost all fires are caused by man, but there are cases which seem to indicate an indubitable possibility of spontaneous combustion in the steppes under the direct action of sun. See about such cases: E. Poepping. *Reise in Chili, Peruand auf dem Amazonenstrom wahrend der Jahre* 1827-1832. Bd. 1. Leipzig, 1835, S. 398; G D. Hale Carpenter. *A Naturalist on Lake Victoria. - With an Account of Sleeping Sickness and Tse-tse Fly.* London, 1920, pp. 76-77.

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See: M. A. Ugov. Composition and tectonics of the deposits of the Southern region of the Kuznetsk coal basin. Novonikolaevsk, 1924, p. 58: idem, Subterranean fires in the Prokopyevsk region - a geological process, Vestnik Zapadno-Sibirskogo geolo- go-razvedochnogo tresta, 1933, no. 4, p. 34; and: V. A. Obruchev. Subterranean fires in the Kuznetsk basin, Priroda (Nature), 1934, no. 3, pp. 83-85. Already J. F. Hermann (who in 1796 discovered the Kuznetsk coal basin) indicated to these phenomena. See: B. F. J. Hermann. Notice sur les charbons de terre dans les environs de Kouznetz en Siberie. Nova acta Academiae scientuarum Imperialie Petropolitanae. SPb, 1793, pp. 376-381. Compare: V. Jaworsky und L. K. Radugina. Die Erdbrande im Kuznezk Becken und die mit ihnen ve bundenen Erscheinungen, Geologische Rundschan, 1933, Hf. 5; V. Jaworsky and L K. Radugina. Coal fires in the Kuznetsk basin and the related phenomena, Gomyi zhumal, 1932, no. 10, pp. 55 (In Russian).

The most probable cause is a series of biochemical phenomena tied up with the activity of thermophilic bacteria. For peatbogs, we have also direct observations of the past years made by B. L. Isachenko and N. I. Mal'chevskaya.[23]

This phenomenon is now requiring a scrupulous investigation.

109. Such areas conserving heat in winter and summer, as well as hot springs, were precious gifts of nature to a Paleolithic man who had to use them in the way they are or recently were used by the tribes and nationalities found by us in the still existing Paleolithic stage.

With the great capability to observation of the man of that time, with his proximity to nature, such places indubitably attracted his attention and had to be used by him, especially during the eras of the glacial period.

It is curious that the use of the same biochemical processes is observed in the area of the instincts of animals. It may be noticed in the family *Gallinacene,* among the so called brush turkeys, or megapodes (*Megapodidae*) of Oceania and Australia who use the fermentation heat, i.e. a bacterial process, for hatching fledglings by means of forming big heaps of sand or earth, with the admixed organic remains that can rot.[24] These heaps may reach four meters high, their temperature may be 44° C and more. The megapodes seem to be the only birds possessing this instinct.

It is possible that the ants termites persistently rise the temperature of their habitation places.

These weak attempts are incomparable with the planetary revolution carried out by man.

As the source of energy, of fire man used the products of life: dry plants. Many myths on the acquisition of fire were created and came to us.[25] However the most characteristic is the fact

[23] See: B. L. Isachenko and N. I. Mal'chevskaya. *Biogenic spontaneous heating of the peat crumb,* Reports of the Academy of Sciences, 1936, vol. IV, no. 8, p. 364 (in Russian).

[24] See: A. Brehm. *Life of animals.* 4th, quite recast and considerably enlarged edition by the professor Otto Zur-Strassen. An authorized translation (in Russian) edited the professor of the Psycho-neurological Institute and the SPb. Medical Institute for Women, N. M. Knipovich. Vol. 7. *Birds.* SPb, 1912. p. 15.

[25] See: I. G. Frazer. *Op.cit.*

that man used for this purpose the techniques hardly observed by him in the cases of forming of fire in the biosphere before man had discovered it. The most ancient techniques seem to have been the transfer of muscle strength of man into heat (intense rubbing of dry objects) and stirring sparks out of stones with further seizing of fire. On the end, a complex of preserving fire became worked out in everyday life a hundred thousand years or more ago.

The surface of the planet has changed abruptly after this discovery. The bonfires sparkled, went out, and reappeared in all places where man lived. Owing to that, man succeeded in surviving the cold climate of the glacial epoch.

Man created fire in the environment of the living nature exposing it to combustion. By this way, by setting fire to steppes and forests, man got a greater force as compared with the surrounding animal and plant world. This force isolated him among other organisms and gave a prototype of his future. Only in our times, in 19-20th centuries, man conquered another source of light and heat—electrical energy. The planet became still more shining, and we are now at the beginning of the period, the importance and future of which yet remains outside of our attention.

110. It was only after many tens or hundreds of thousand years that man mastered other energy sources, some of which, for example, steam energy, were a direct consequence of the discovery of fire.

During long millenia man sharply changed his position in the living natural environment and radically transformed the living nature of the planet. This began as early as in the glacial period when man started taming animals, but during long millenia this process did not affect clearly the biosphere. During the Paleolithic period, only dog turned out to become connected with man.

A radical change occurred in the Northern hemisphere after the withdrawal of the last glacier, after the end of glaciation.

This was the discovery of agriculture with food created independently of the wild nature, and the discovery of cattle- breeding. The latter discovery, beside its importance for food supply, accelerated man’s traveling.

It is difficult now to definitely conceive the conditions under which agriculture could arise. The nature surrounding man in that time, about twenty thousand years ago or more [26], was strikingly distinct from that observed in the same places now. It is not only the consequence of the nature transformation by the cultural work of mankind (as it was thought still recently), but also of the spontaneous change in the environment at the stage of the glacial period we are living now. We clearly see that even during a smaller historic period, the past 5-6 thousand years, man lived through geological changes of the biosphere. The areas of China, Mesopotamia, Asia Minor, Egypt, perhaps of some part of the Western Europe, beyond its taiga of that time, were strikingly distinct from the same regions in our time, which cannot be explained by the cultural work of the mankind and its inevitable, though predicted by man, consequences. Simultaneously, with the cultural work of the mankind, the spontaneous process of the advancement of the glaciers for a hundred or two thousand years was taking place, diminishing or increasing in its intensity. This was a process characteristic of the anthropogenic era, and on the whole, this process was dying away.

111. Under the present strength of culture, farming cannot cover all surface of the dry land. After recent calculations, the area embraced by farming is not more than $129.5 \cdot 10^6$ square kilometers, which comprises up to 25.4% of the Earth's surface.[27] If one takes land alone, the result will be 86.3%. Probably, this number must be viewed upon as an overestimation, but, as a whole, it gives an idea about that enormous cultural biogeochemical energy with which the mankind changed the surface of the planet during 20 thousand years or more. One ought to take into consideration that the Arctic and Antarctic, the semideserts and deserts of North and South Africa, of Central Asia and Arabia; the North American prairies; a significant part of Australia, the Alpine plateaus and high mountains of Tibet and North America hardly yield or do not yield at all to farming. Such

[26] It seems to me that N. I. Vavilov's observations over the centers of creation of domesticated animals and plants will make us to admit for the beginning of agriculture a much earlier date than 20 thousand years ago.

[27] H. Rew. *Agricultural Statistics.* Encyclopaedia Britannica, 1. London, 1929, p. 388 (14,5 millions of square kilometers, or 10% of land without Antarctica. - Edit. note).

areas taken together constitute one fifth of the land area or more. It is to be said that for man in the beginning of his culture work, even under the condition of availability of fire, both taiga and tropical forests represented and almost insuperable obstacle with relation to agriculture. Besides that, man had to struggle for a long time with the resistance put up to him by insects and wild mammals, plant parasites and weeds, which took away a great, often overwhelming part of the products of his labor. Even now, in our agriculture, weeds seize 1/5 to 1/4 of the harvest: initially, this figure has been certainly a minimum one.[28] Now we have, owing to the socialist construction in our country, somewhat more exact figures for the calculation of the intensity and potentialities of this form of the biogeochemical energy of the mankind. Firstly, the area under crops is greatly expanding in our country. As it is indicated by N. I. Vavilov and his coworkers, only during two past years (1930-1931) the sown area increased by 18 millions hectares, which would require decades by old standards.[29] Under the planned estimates made by eminent specialists, the general picture of farming in our country is outlined. The area of the USSR is 2.14-10^{7} square kilometers which adds up to 16,6% of dry land. From this, there are 5.68T0^{6} square kilometers unfit for farming outside of its northern frontier, while

on the whole, unfit for farming are presumably 11.85 10 square kilometers. As to the land serviceable for agriculture, its area constitutes 9.53-10^{6} square kilometers. Thus most space of our country lies outside of the frontiers of the present-day agriculture or is registered as unsuitable for farming.[30] However this area may be significantly bettered and diminished. The plan of the state meliorative works as calculated by L. I. Prasolov[31], would permit to

[28] A. I. Maltsev. *The most recent achivements in studying the weeds in the USSR.* The achievements and perspectives in the area of genetics and selection. Leningrad, 1929, p. 381. (In Russian).

[29] N. I. Vavilov, N. V. Kovalev, N. S. Pereverzev. *Plant breeding in connection with the problems of agriculture in the USSR.* Plant breeding, vol. 1, pt. 1. L. M., 1933, p. VI (In Russian).

[30] L. I. Prasolov. *Land reserves for plant breeding in the USSR.* Ibid, p. 31. (In Russian).

[31] Ibid, p. 37.

increase this area approximately by 40%. It is evident that this is not the limit of potentialities and one may hardly doubt that in the case when the mankind finds it necessary or desirable, it could gather energy which would seize for agriculture all the surface of the Earth and, perhaps, something more.[32]

112. Also in China there exists a system of intense farming having formed during generations and having existed more than 4000 years in a rather stable mode in a steady state, occupying an area of 10 millions square kilometers. Of course, the area changed during millenia, but an elaborated system and the habits of agriculture were conserved and influenced the surrounding daily life and nature. Only most recently, in this century, this population mass came into an movement, and the multimillennial habitudes are being destroyed. For China, one may speak about a vegetative civilization (Goodnow).[33] During endless generations, at the time interval more than four thousand years, the population rested on the whole at one and the same place continuously but changed the surrounding nature of the region and in its daily life identified itself worth it. Perhaps in China, the most part of farming production of the Earth is got, while the population is always threatened by malnutrition.[34] More than three quarters of the pop

[32] The possibility of the seizure of the oceans in such or another form has many times appeared in scientific utopias already in the time when one recognized clearly the physical nothingness of man before the strength of the oceans. In a curious utopia by B. P. Weinberg (*Twenty thousand years of the works on the annihilation of oceans. An essay on the history of the mankind from primitive state to the year 2230.* Sibirskaya priroda, Omsk, 1922, no. 2, p. 30. In Russian), the author says on the stage of human history which will come when the reproduction of man will embrace all the land: this is the stage of the annihilation of the oceans. B. P. Weinberg admits that in the 21st century this problem will begin to be discussed seriously. To some degree, such questions are indubitably real for human reason. The example of the Netherlands from the past (of course, at a small scale) and the idea of Goethe’s *Faust* (also at a diminutive scale for the late 18th and early 19th centuries) already are real anticipation of the future. At our time, the question of stationary offshore floating bases in the seas and oceans— this question and related studies also are nothing more but the first rudiments of the future.

[33] F. Goodnow. *China. An Analysis.* Baltimore, 1926.

[34] *G. B. Cressey. China s Geographic Foundations: a Survey of the Land and its People. New York—London, 1934, p. 101.*

ulation are farmers. The largest part of China is an ancient country of well established farming with soil tilled so close to the possible economic limit that one hardly can secure greater harvests. "The roots of the Chinese go deep into the earth. The most significant elements in the Chinese landscape is thus not the soil or vegetation or the climate, but the people. Everywhere there are human beings. In this old, old land, one can scarcely find a spot unmodified by man and his activities. While life has been profoundly influenced by the environment, it is equally true that man has reshaped and modified the nature and given it a human stamp. The Chinese landscape is a biophysical unity, knit together as intimately as a tree and the soil from which it grows. So deeply is man rooted in the earth that there is but one all-inclusive unity—not a man and the nature as separate phenomena but a single organic whole".[35] Notwithstanding this incessant work of many millenia, only slightly more than 20 per cent of the area of China is under farming[36]; the rest eventually can be improved, for a country so large and rich in natural gifts, by means of state measures only possible under the level of science of our time. Owing to the work of the population during millenia, an average of 126.3 people live at every square kilometer, over the space of 3,789,330 square kilometers. This is almost a limit for the maximum use of agricultural area. As Cressey indicates with right, this is something like a climax formation within the framework of the ecological botany. "Here we have an old stabilized civilization which utilizes the natural resources up to the limit. Until new external forces stimulate change, there is but little internal readjustment."[37]...''The Chinese landscape is vast in time as well as in area, and the present one is the product of long ages. More human beings have probably lived

[35] Ibid, p. 1.

[36] I took G Cressey's data about the total quantity of tilled earth over the provinces and areas of small agriculture and compared it against the area of the Chinese territory. From this comparison, I obtained the figures of 16.7 to 18.5 per cent. These data relate to the years 1928 and 1932. Cressey in his statistical review (p. 395) gives for agricultural China (i.e. except Da Hinggan Ling mountains, Central-Asian steppes and desert, and the area adjacent to Tibet) with its 379 millions of square kilometers and population over 477 millions, the figure of 22 per cent area. Thus it is clear that the population is concentrated upon a small area used in full.

[37] Cressey, *op.cit,* p.3

on the plains of China than on any similar area on Earth. Literally trillions[38] of men and women have made their contribution to the outlines of hills and valleys and to the pattern of the fields. The very dust is alive with their heritage".[39] This culture of four thousand years ought to pass the stages of more awful and tragic past before assuming its stabilized form, for the past of the Chinese nature developed in a quite different environment, among quite other milieu, humid forests and marshes; to conquer and cultivate them, to destroy forests and overcome their animal population, one needed tens of thousand years. The recent discoveries show us that at the same time when in Europe man survived the movements of the ice masses, in China culture became formed under the conditions of the pluvial period.[40] Evidently, the roots of the irrigation system owing to which the Chinese agriculture exists descent deep into the past (for 20 thousands of years and more). Up to the late 20th century, such biocenosis could exist in a certain equilibrium. Still it could only exist thanks to a certain isolation of China; from time to time, population was being decimated by murder, hunger, starvation, and floods. Irrigation was too weak to cope with the force of such rivers as Huang He. Now this all is quickly going into past.

In China, we see the last example of an isolated civilization which had lived millenia. We saw that in the early 18th century, when the Chinese science was at its height, China stood at a historical turning point and missed a possibility to enter the world science in the due moment. This happened only in the second half of the 19th century.

113. Farming alone could reveal itself as a geological force and change the surrounding nature when parallel with it, cat-

[38] Certainly, one is not to say about trillions but about a much greater number of population having lived on the Chinese soil, for we may take it for granted that people of the genus *Homo* and of the genus *Sinanthropus* lived there during hundreds of thousand years. The forming of a new species or genus that could generate modem people could take place in one family or one herd, but also on a rather great area. However, even in the first case, the number of organisms generated by one pair ought to be much more than 10*[0] (during hundreds of thousand years), even if we introduce amends assuming common ancestors for a separate individual along paternal lines. See: E. Le Roy. *Op.cit.*

[39] Cressey. *Op.cit.,* p.3

[40] As for ancient China see: M. Granet. *La civilisation Chinoise.* Paris, 1926, p. 82 ff.

tie-breeding arose: i.e. when simultaneously with the selection and breeding of plants necessary for human life, man chose and began to breed the animals useful to him. By this, man unconsciously performed a geological work stimulating greater reproduction of certain species of the plant and animal organisms, creating to himself always accessible concentrated food, and supplying food to some species of animals in which he needed. By cattle-breeding, man did not solely obtain guaranteed food but also increased his muscle force, which permitted him to enlarge the area occupied by his farming.

In working cattle, man obtained a new for him form of energy which permitted to feed more people, to create big settlements and city culture, to free himself from the threat of inevitable hunger.

In all this, man did not quit the boundaries of living nature.

During the past centuries, in our century of steam and electricity, the working force of cattle, the muscle power of animals and man begins to become secondary for the growth of agriculture. But even up to now man does not leave the boundaries of living nature for the primary source of the energy of electricity and steam is the same living nature in the form of living vegetation or, still more now, the living organisms of the past transformed through geological processes. This energy is obtained from coals and oils. In the end, by this way man is always utilizing the energy of solar rays having pierced through the living substance (contemporary to them) and preserved in the form of deposits: the rays which had illuminated the Earth for hundreds of millions years before man appeared on the Earth.

Agriculture and cattle-breeding were the first manifestations of the biogeochemical cultural energy directed by the reason and creating new conditions of man's biospheric abode. It was mainly living nature that became strongly transformed. As to the inert matter of the biosphere, during many tens of thousand years it was only influenced by man to a degree hardly comparable with the active change by him of the living environment that surrounds him.

As a result of that work, a new face of the Earth has been created: the surface of the Earth acquired the outlines within which we live now and which only became evident during the past millenia. Now the change is being manifested every decade with an increasing strength.

Still agriculture as such, even without cattle-breeding, transforms the surrounding nature strikingly. For in the living environment of man all free areas are occupied by living substance, and for leading a new life, man ought to clear the room for it, to clean the area from other life. More than that: he must continuously protect the life (which he is creating) from the surrounding pressure of life, from the animals and plants rushing upon the blank space opened by him. He has also to guard the fruits of his labor against animals and plants which otherwise would destroy them: against mammals, birds, insects, fungi, etc. We shall see that even now he cannot cope with this task in the full.

Agriculture, together with cattle-breeding, are continually protected by human thought and labor and, in the end, carry out an immense geological labor. The forms of life become extinguished, the new ones are created: the new species of animals and plants created by the thought and labor of man on the basis of the old forms which had been created under other circumstances. However, also the world of wild animals and plants not touched upon by man immediately cannot remain unchanged in the new vital set-up created by the biogeochemical energy of man.

114. Cattle-breeding itself, without agriculture, causes huge changes in the surrounding living nature. For it takes away food and condemns big mammals (except a few species selected by man), to quick or slow dying out. Man appeared in the early Tertiary epoch, in the period when big mammals reigned in the biosphere, as it has been correctly indicated by Osborn.[41]

Nowadays, one may say that these mammals practically become extinct, or they are quickly dying out and only remain in the reservations and parks where there numbers is stationary. The observations made in these big reservations show that even independently of human will, a stationary dynamic equilibrium

[41] *H. Osborn. TheAgeofMammals in Europe, Asia and North America.N.Y., 1910.*

becomes established there: reproduction is being regulated by limited quantity of food for the herbivorous and by the numbers of the carnivorous for whom these latter serve as food.[42] Under malnutrition and the weakening of their organisms, the level of reproduction is defined, besides this, by diseases caused by living microorganisms. Still all conserved numbers of wild herbivorous animals may not be compared with the number of domesticated animals: horses, sheep, cattle, swine, goats, etc. One may think that their numbers in the Tertiary epoch hardly exceeded the numbers of contemporary domesticated mammals. We do not know this figure exactly, but still we have some quantitative notion about it. Now it hundred-fold exceeds the figure of human population on earth. After M. Smith (1910)[43], in the early 20th century it equaled 1.38-10 After H. Rew[44], in 1929 this figure reached (for horses, cattle, sheep, goats, and swine) 1.57-10 ^{10}. Omitted here breeds of domestic animals do not change the order of the value. Thus, one may say that this figure, expressed in billions, varies from 15 to 138 billions, which much exceeds the numbers of people. The figure varies greatly for it is a subject of the man's control. For example, after G. Dufrenoy[45], from 1900 to 1930 the numbers of cattle decreased by one quarter, displaced by machines. In proportion as man masters new sources of power, the cattle rapidly decrease in number before our eyes: for example, the numbers of horses, donkeys, or mules decrease thanks to the grow of the numbers of tractors and automobiles.

115. Cattle-breeding and agriculture appeared in various places not simultaneously, 20 to 7 thousand years ago, and the intensity of both gradually increased with time. The transition from nomadic (migratory) life of hunters or food-gatherers to the modem settled life based mainly upon farming took place in diverse times at the margins of the desert zone, under temperate

[42] *See: Stevenson-Hamilton. The South African Edem; from Sabi Gume Reserve to Kruger National Park. London, no. 4, 1936.*

[43] M. Smith. *Agricultural Graphics. United States and World Crops and Live Stocks.* Bull, of US Department of Agriculture, Washington, 1910, no. 10, p. 388.

[44] H. Rew. Encyclopaedia Britannica, t. 1, 1929, p. 388.

[45] *G. Dufrenoy, Revue generate des sciences pures et appliquees. Paris, 1935, no. 46, p. 72.*

latitudes, from what is now Morocco to Mongolia. This transition was an eventual result of climatic changes after the retreat of the last glacial sheet and the weakening of rains of the pluvial[46] period.

Seven or eight thousand years ago, first strong states based on agriculture and first great cities emerged. Man obtained the possibility to reproduce himself with intervals smaller than earlier. The city civilization of the Celtic and Berberian states and of their predecessors (Egypt, Crete, Asia Minor, Mesopotamia, North India, China) arose. Here we also enter the ages for which legends have been conserved and come to us, and for which there are innumerable material monuments discovered by archeological excavations. Their importance and effectiveness have continuously and rapidly increased during the past three centuries.

One may think that during past 5 to 7 thousand years, a continuous and ever accelerating creation of the nposphere has been happening, and the cultural biogeochemical energy of the mankind has been growing firmly, mainly without any backward movement, but with stops the duration of which ever decreased. The conscience is growing that this increase of cultural energy has no irresistible limits, and that here we deal with a spontaneous geological phenomenon.

116. Here, it is appropriate to present some facts. The beginning of the Egyptian calendar based upon the many years' observations on the Dog Star and having become the foundation of all the Old World chronology (down to our days, when it happened to be spread all over the noosphere) may be dated 4236 B.C. or somewhat earlier.[47] Even before that, 4 to 5 thousand years B.C., a city culture existed in India, Mesopotamia, Asia Minor, with such everyday life technology about which even few years ago we could not suspect yet. This technology was spread over the population numbered perhaps by millions. To the end of

[46] N. Nelson gave recently a concise review of this problem at the world scale. See: N. Nelson. *Prehistoric Archeology: Past, Present, and Future.* Science, 1937, vol. 85, no. 2195, p. 87.

[47] One may only choose between this figure 4236, and another one: 2776 B.C. All the facts now known to us (taking into consideration the course of the growth of historical and archeological studies) indicate that only the first figure is true. See: N. Idel'son. *The History of Calendar.* L., 1925. (In Russian).

that period, three thousand years B.C., travel on animals began, and within 1500 years it became greatly developed and included travel on oxen, camels, horses. As early as 33 centuries B.C., the priests in Mesopotamia used the art of writing. The records were made by a difficult pictographic writing. Approximately 15-16 centuries B.C. the Semites of the Near East discovered the letter alphabet. One may say that for 2 1/2 thousand years B.C., scientific thought became clearly manifested, and for 2 thousand years B.C. in Mesopotamia, the decimal system became discovered. At that time, the old records made a few centuries earlier began to be rewritten and conserved in libraries. Between the 15th and the 14th centuries B.C., we see a wide information exchange in the then cultural world of scientists, philosophers, and physicians. About two thousand years B.C., perhaps slightly earlier, bronze was discovered, evidently in various places at the same time, and about 1400 B.C.—iron (which then came into use after a few hundred of years).

With these great achievements, we have come now to the last centuries B.C., when scientific, artistic, and religious creativity reached enormous heights and laid the first foundations of our civilization.

During the past 500 years, from the 15th to the 20th centuries, the mighty influence of man upon the surrounding nature and his understanding of nature were increasing continuously. During that time the unified culture embraced all the surface of the planet (see § 64), the book printing became discovered, all earlier inaccessible areas of the Earth were recognized, new forms of energy (steam, electricity, radioactivity) were mastered, all chemical elements became coped with and used for human demands, telegraph and radio were invented, the drilling penetrated into the Earth's crust for kilometers, and man rose with his aeroplanes to a height of over 20 kilometers from the surface of the geoid (with apparatuses, over 40 kilometers). The deep social changes supported by people's masses advanced their interests directly to the first plan: now the question of putting an end to malnutrition and hunger is posed really and will not be lost out of sight.

The question of the planned, unified activity for mastering nature and for the right distribution of the wealth is now on the agenda. This question is tied up with the consciousness of the unity and equality of all people, with the consciousness of the unity of the noosphere. The movement cannot be reversed, but it bears a character of a hard struggle still basing upon the deep roots of the spontaneous geological process which may last during two or three generations, perhaps more (but is hardly probable judging from the rate of evolution during the past millennium). In this transitive state which we are living through, among the intense struggle, any prolonged pauses of the process of the now being accomplished transition of the biosphere into the noosphere seem to be hardly probable.

The scientific mastering of the biosphere which we observe is a manifestation of this transition.

This non-accidental nature of this transition and its connection with the structure of the planet, more precisely of its outer envelope[48], ought to be subjected to a most deep (to our possibility) logical analysis in the future, with reference to the concepts of biogeochemistry.

All the above said is a result of an exact scientific *observation* and as such, has to be reckoned with as a scientific generalization, as far as this observation is correct.

This is a scientific description of a natural phenomenon beyond any explanations if it by a hypothesis, theory, or extrapolation.

117. We clearly see now, by observing this way the completely developed scientific disciplines, that there exist the sciences of various types: (1) sciences whose objects, and therefore also laws, embrace all the reality, including both our planet with its biosphere and outer space. These are the sciences whose objects answer to the main and common phenomena of reality; (2)

48 In reality, it is perhaps the second (counting from outside) envelope of the Earth's crust, namely stratosphere, occupied by life, mainly by man: the noosphere. Then it must be reckoned among the components of the biosphere (see: V. I. Vernadsky. *On the limits of the biosphere.* Izvestiya AN, ser. geol., 1936, no. 1, p.3 24. In Russian). Presumably the higher spheres, 60 to 1000 kilometers, do not belong to the Earth's crust but ought to be viewed upon as the divisions of the planet analogous to the Earth's crust, i.e. they are a concentric area of the planet. Then the Earth's crust is the second area of the planet, and the biosphere is the outer envelope of this second area. I think that this problem will be cleared up soon.

Another type of sciences is tied up with the phenomena peculiar and characteristic for our Earth.

In the latter case, one may theoretically admit two categories of scientific (or possibly studied by science) objects: the phenomena of a general planetary nature, and the individual and purely terrestrial phenomena.

However, now one cannot reliably and with sufficient certitude discern between these two cases. Such distinction is a task for future.

The latter case includes all sciences on the biosphere, among them human sciences and Earth sciences as well (botany, zoology, geology, mineralogy), in all their scope.

Taking into consideration this state of our knowledge, we may discern the manifestations of the influence exerted upon its structure within the biosphere, by two areas of human reason: (1) the manifestations of the influence of sciences common to the entire reality: physics, astronomy, chemistry, mathematics; (2) the manifestation of the influence of the Earth sciences: biological, geological, and human sciences.

118. A special position is occupied by *logic,* most closely connected with human thought and equally embracing *all the sciences,* both human and mathematical.

Essentially, it must be included into the area of the planetary reality, but it only with the help of logic that man can understand and scientifically recognize all the reality as a scientifically constructable Cosmos.

Scientific thought is both individual and social phenomenon. It may not be severed from man. A personality can never quit the area of its existence, even using the deepest abstraction. Science is a real phenomenon and (like man himself) is most closely and inseparably tied up with noosphere. Personality is annihilated ("dissolved") in the case when it leaves the logical sphere embraced by its reason.

However, the apparatus of the reason closely tied up with the vCorld, with the concept (and the logical structure of a concept is a complex one, as we shall see in a digression on logic in the end of this book) does not exhaust all knowledge of man about reality.

We see and know (but we know it at everyday-life level and not scientifically) that scientific creative thought exceeds logic, including dialectical logic in its diverse aspects. Personality, in its scientific achievements, bases upon phenomena not covered by logic even in its enlarged understanding.

Intuition, inspiration—this is the foundation of the greatest scientific discoveries which begin from this stage and then proceed rationally and in a strictly logical way. However, intuition (inspiration) is not caused by a scientific or logical thought but is tied up (in its genesis) with a word and a concept.

With this basic phenomenon of the scientific thought history, we enter the area of phenomena not understood by science until now. Still we ought not to leave it out of sight, on the contrary: we must strengthen our scientific attention to this area.

Now it is the field of philosophical constructions which have elucidated some problems but, on the whole, the area of these phenomena remains in a chaotic state.

The most deep and interesting attempt at studying it is the Hindu philosophy, both ancient and contemporary. Here one sees profound approaches to this area very little touched upon by science[49]. Our science does not know how deep these approaches can lead and direct the human thought.

We only see that scientific analysis of reality is greatly influenced by that vast area of phenomena having a world of artistic constructions peculiar to them. This world is scientifically regular and in a most close way tied up with the social order and in the end, with the structure of the biosphere, still more of the noosphere. In some its parts, for example, in music or architecture, those artistic constructions cannot be reduced to verbalized concepts. The control of this cognitive apparatus (little reflected by logic) is a task for future, with reference to scientific understanding of reality.

[49] To avoid misunderstanding, I must make a reservation that I do not mean theosophic search essentially far from both modern science and modern philosophy. In the new Hindu thought, as well in the ancient one, there are philosophical trends not in the least contradicting our modern science, or contradicting it to a smaller degree than many philosophical systems of the West. Such are, for example, some systems tied up with Advaita-Vedanta, or even (as far as I now) religious-philosophical search of Aurobindo Ghoshi (1872—1950), a prominent contemporary religious thinker.

119. Biogeochemistry in its greater section (the object of this section are atoms and their chemical properties) must be related to the category of generalizing sciences. Nevertheless, as a part of geochemistry, as geochemistry of the biosphere, biogeochemistry is science of the second type, tied up with a definite small (in relation to the Universe) natural body—the Earth. (Or in the most generalized case—a planet).

Studying the manifestations of atoms and their chemical reactions at our planet, biogeochemistry in its roots transcends the limits of the planets; it is based (like chemistry and geochemistry) upon the cognition of atoms and thus is connected with the problems more difficult than those peculiar to the Earth or to any planet; with science on atoms, with atomic physics, with the foundations of our understanding of reality in its cosmic aspects.

However, this is less clear with relation to the phenomena of *life* which are studied by biogeochemistry in their atomic aspect.

Do the problems of biogeochemistry transcend the limits of a planet also in this relation? And how far do they transcend these limits?

Section four

LIFE SCIENCES IN THE SYSTEM OF SCIENTIFIC KNOWLEDGE

CHAPTER VIII

Life—an eternal or temporal manifestation of reality? The natural bodies of the biosphere: living and inert. The complex natural bodies of the biosphere: the bioinert bodies. In them, the interface between the living and the inert is not violated.

120. We do not understand at all the position of life within the scientific world outlook. There is a tradition established in scientific literature, to pass over this question in silence and to leave it entirely to the philosophical and religious constructions which are now but loosely connected with the scientific ones, and remote from reality and scientific certitude, even contrary to them.

Neither philosophical nor religious thought of the modem humanity keeps pace with the rapid rate of the growth of the natural science in the 20th century. Because of this, the philosophical or religious solution of the problems increasingly loses its importance in science.

Science itself must approach this problem, but does not do
it now.

Not only do we not know where the line of life ought to be placed in the scientific reality; we even *pass over* this problem *in our research.*

Now, when biogeochemistry begins to connect (definitely and scientifically) life with the structure of atoms and with the isotopes, and not, as before, only with the macrophysical and chemical forces—now scientific thought may not further remain in such a stagnant position.

It is unknown whether life is only an earthly, planetary phenomenon, or it must be acknowledged as a cosmic manifestation of reality, like such manifestations as space-time, matter, and power. Nowadays, in his scientific work one may adhere to any of both these views without any contradiction to the well established scientific data. Nonetheless, the initial assumption (that life is solely earthly and not cosmic phenomenon) will perhaps not to be defended in a short time.

During long time, science recognized life only as a phenomenon peculiar exclusively to the Earth. Evidently, we may not look upon it as upon a usual planetaiy phenomenon, for over the major planets, remote from the Sun (for example, Jupiter, Saturn, Uranus, and, perhaps, Pluto), low temperature makes improbable life similar to the earthly one, if we do not accept the possibility of other forms of life, apart from those determined by the thermodynamic and chemical field of *our* biosphere. Such ideas had been advanced repeatedly, for example, by Prayer, who admitted the existence of life under high temperature. For the time being, these scientific admissions have not been supported by facts. They only allude to the possibility hypothetically admissible. In the area of very low temperatures, outside of the biosphere limits, the latent life is undoubtedly conserved, and seemingly, for an indefinite time.

For our Earth, we do not know (with any degree of probability) the geological deposits formed in the period of its history when it lacked life[1]. But the absence of such deposits still remains unproved. One may admit two mutually contravening opinions:
(1) the life on the Earth appeared during the geological time, and
(2) the life existed since the time of the most ancient (so far as we know) Archean rocks. The geologists holding this second opinion as a working hypothesis, express their view by changing the name of these rocks into “Archaeozoic” instead of “Archean”. Probably, the more ancient Archean rocks include a greater portion of the magmatic rocks, and one of the main purposes of geology is to

[1] For the Earth, we now do not know with a geological certitude the deposits formed in the absence of life. Even in the most ancient Archean layers, the exis-' tence of life is clear in the deposits. The weathering processes in these layers were the biogeochemical processes just like the contemporary ones. The azoic layers are not recognized anywhere with sufficient reliability; the most ancient parts of the Earth’s crust contain metamorphosed sedimentary rocks. But we must take into consideration that this result is not definitive for the most ancient Archean layers still remain insufficiently studied. The inference is not a final one as yet.

determine exactly and scientifically whether this is true. Have we reached in the geologically most ancient metamorphic rocks lifeless sediments? There are weighty grounds to doubt it, but the doubt is not an argument. A solution of this question is quite possible and now is on the agenda.[2]

On the another hand, there is much to indicate that life even now exists not only on the Earth, but also on another planets. One may take it for something more than probable.

We have rather plausible indications on the possibility of the existence of life (in the main features, similar to our one) on Mars and Venus. Here, the question also is in such state that one is justified in expected for its swift and incontrovertible scientific solution, to one side or another. So far, we have no such a solution, but it seems probable to me that this solution will prove to be positive.

Under the given circumstances, it is possible to conjecture (as it seems to me) that in the nearest time, the real existence of life on the planets and not only on the Earth will be proven.

121. Proceeding from this, it is already now *scientifically* possible to formulate in science a general question whether life is only an earthly phenomenon or it is only peculiar to the planets or it to some degree and in some form reflects the phenomena of a greater scale, the space phenomena, which are deep and eternal just as atoms, energy, and matter are for us in that they geometrically elucidate the space-time.

Taking into account the feeble development of our knowledge in this area, one may even admit that the earthly and even planetary life is a particular case of the manifestation of life, just as the northern lights or the lightnings of the earthly atmosphere are the particular cases of the manifestation of the electric phenomena. Here we are in the area (almost alien to science) of scientific hypotheses and even scientific phantasy, for one may take

[2] The most ancient organisms, probably belonging to the type of the unicellular algae, have been found in the southwestern Greenland, in the shists of Innwit formation itruded by the granites whose age is now determined from 2.7 to 2.8 billion years. The organisms themselves are more ancient than these granites. As to the rocks enriched in the graphite of organic origin, they have been met in even more ancient (up to 3.5 billion years) Lower Archean layers of the Earth's crust. - Edit. note.

as such the ideas of life in the areas with temperature and gravitation unusual for Earth.

Even such an admission may not be rejected by us scientifically. So remote are we from a scientific understanding of life.

In philosophy, including its most different systems, the problem of the eternity of life was and is formulated many times. In a series of philosophical systems, life is considered to be one of the main and customary manifestations of reality[3].

Now, the question of life in the Cosmos ought to be put forward 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 ones, are to be included into the group of sciences studying the general phenomena of reality.

122. Under this aspect, it is suitable to use in biogeochemistry one logical concept taken out of the area of the exact sciences of nature. In the biosphere, this concept manifests itself in especially many forms and very brightly, but the philosophical and logical thought still neglects it. Though the use of this concept is inevitable, its importance seems to me insufficiently recognized.

I do not know any profound philosophical and logical analysis of this concept.

It is the concept of a *natural body.* We shall name so (in the biosphere) any object logically distinct from its environment; formed as a result of a regular natural process taking place in the biosphere or generally in the Earth's crust.

There are millions of millions of possible "natural bodies": every rock (and the forms of its bedding: batholite, stokwerk, stratum, etc.), every mineral (and the forms of its bedding), every organism as an individual or as a complex colony, any biocenosis

[3] In relation to the philosophical ideas of the Mediterranean and West European culture, see literature indications: R. Eisler, *Worterbuch der philosophischen Begriffe. Historisch-quellenmassig bearbeitet.* Hrsg. unter Mitwirkung der Kunstgesellschaft. Bd. I—III. Berlin, 1927-1929. Even more bright and lively are these ideas in the philosophical systems of Indian thought. See: S. Radhakrishran. *Indian Philosophy.* London, 1929-1931.

(simple or complex), any soil, silt, etc.; cell, its nucleus, gene, atom, its nucleus, electron, and so on; capitalism, class, parliament, family, commune, etc.; planet, star, etc. From these examples we see two categories of concepts: (1) the concepts whose designate really exists in the nature and is not a mere creation of the logical process. Such are a certain planet, a certain soil, organism, etc.; (2) the concepts created, completely or mostly, by a complex logical process of generalizing innumerable facts or logical concepts. Such are soil, rock, star, state, etc.

Real science is built up through identifying *natural bodies,* and in scientific work it is important to simultaneously take into consideration both the concepts corresponding to natural bodies and the really existing, scientifically defined natural bodies.

With relation to a natural body, a word and a concept unavoidably do not coincide.

The concept which corresponds to a natural body is not something constant and unchangeable, it alters sometimes, very suddenly and essentially, with the course of scientific work and life of humanity.

The word which corresponds to a concept of a natural body may exist for centuries and millenia.

Philosophy can in no case exceed the limits of the con- cepts-words. It has no possibility to approach the concepts-objects. It is the main distinction between the logical work of a scientist and a philosopher.

There was a time (for example, when Democritus of Abdera lived, 460-370 B.C.) when it was otherwise. But now this time is irrevocably over.

In contradiction to philosophy, science in its logical and methodological analysis, never restricts itself only to the words which correspond to the natural bodies. Science takes always into account (tests with scientific experience and observation) the natural bodies themselves, that correspond to the concepts.

This distinction is especially sharp in the area of the exact natural sciences, as compared with the vast field of the problems of the human sciences, although in the human sciences too one inevitably addresses the “natural bodies”, immediately and increasingly, to a degree in which the scientific techniques sharp en. In this respect, the 19th and 20th centuries here smooth over the existing difference between the humanities and natural sciences. The exactitude and trustworthiness of human sciences have already increased, man himself being a “natural body” for the scientific thought. And we only are present at the beginning of the change.

Later I shall dwell on the questions tied up with the logical significance of a “natural body” (see the digression on the logic of natural science in the end of this book).

But here I only touch upon this problem to a degree which is necessary for the understanding of all that follows.

I will note that the modem logic almost ignores this problem and did not sufficiently work it out. Meanwhile, more than 2500 years ago, even before Aristotle, the great naturalist and philosopher Democritus, and probably even the more ancient thinker Leukippes, had a clear view on this problem. But it ceased to be elaborated when Aristotle’s logic comprehended the scientific and philosophical thought. Now we only may make deductions with reference to the probable development of the ideas and works of Democritus, to the existence of literature that reflected them during the centuries preceding to our era.

All this literature was lost more than a thousand years ago, and only archaeological excavations will possibly discover it to us.

But the fact is that this literature did exist and influence the human creative thought in the biosphere during millenia; only we do not know the course of the manifestation, and dying out of this literature.[4] Probably without any connection with this manifestation, we meet the same phenomenon also in the history of the Indian logic.

Perhaps, this phenomenon has been called to being by the

[4] The archaeological excavations and successes of the history of the Ancient East and Egypt change our concepts. The historical-critical study of ancient Greek authors and the profound investigation of all the material accessible for this study make us to leave the scepticism which is scientific and useful by itself, but often has lead to the mistakes and the barrenness of the knowledge in this area. The history of technology shows us an enormous sum of scientific knowledge which 10-20 years ago one even did not resolve to speak about. Nowadays, the civilization that had existed in the 7th—6th millenia B.C. seems to us fairly more significant than we had considered it still recently.

identical causes: the absence of the social-political life conditions and of the conditions for the self-manifestation of the scientific work of a personality, free from the pressure of philosophy and religion.

123. In biogeochemistry, one must give the first place to the natural bodies characteristic of the *biosphere*: the living natural bodies and the complex natural bodies including both inert and living matter: bioinert bodies, which do not exist outside of the biosphere.

Some of such natural bodies are already long time ago determined and identified by the everyday life. Such are men, animals, plants, forests, fields, etc. An enormous quantity of such natural bodies has been created and goes on to be created by science: e.g., plankton, benthos, etc. The movement of scientific thought is determined, first of all, by the exactitude and quantity of such concepts of natural bodies whose number increases continuously with the development of science. Simultaneously with the establishment of new natural bodies, the old ones are becoming more exact, and sometimes a new science emerges in the course of the analysis of the old concepts.

As a live example of such process (in which I happened to participate in my youth, and in which my thought grew), it is enough to recollect and to reflect on the creation in Russia in the late 19th century of a mighty movement tied up with the emergence of the new concept of *soil*; movement that led to a new understanding of the soil science. In the literature of that time, first of all under the influence of V. V. Dokuchaev, an eminent naturalist, we find many echoes of a new elucidation of the old concept of soil as a natural body; the concept talked about long before by Dokuchaev, but not understood yet.[5] The idea of soil as a natural body distinct from rocks and minerals is a core one, and as it always happens, V. V. Dokuchaev's understanding of it was not a unique and definitive one.[6]

[5] *See: V. I. Vernadsky. A page from the history of soil science (In memoriam V. V. Dokuchaev). Nauchnoe slovo, 1904, no. 6, pp. 5-26.*

[6] See the important works of the soil scientist A. I. Nabokikh (e.g., *To the question of soil classifications,* Warsaw, 1900; *The classification problem in soil science.* Part 1, SPb, 1902).

Another new concept of a natural body is the concept (fundamental for geochemistry and thus also for biogeochemistry) of living substances as of the sets of living organisms.[7]

124. It is very significant that one observes in the biosphere the natural bodies of sharply different character: *inert natural bodies,* for example, mineral, rock, crystal; chemical compound, created in a laboratory; products of human labor, nests, hydrometeors, volcanic products, etc. Clearly different from them are living organisms, *living natural bodies*: millions of species and millions of millions of the individuals. The sets of living organisms, the *living substances,* also are natural bodies, namely, the living ones. They may be the sets of individuals of one and the same species—the *uniform living bodies',* or of morphologically different species—the *heterogeneous living bodies.* There is a series of other complex living natural bodies, for example, the bio- cenoses, etc.

In the biosphere, one may identify a set of natural bodies consisting at the same time of living and inert matter. To this set, for example, soil, silts, etc. belong. The study of such natural bodies plays an enormous part in the science, for with their help one may study the process (as such) of the influence exerted by life upon the inert nature: the dynamic, steady state equilibrium, the organized nature of the biosphere. One may build logically an infinite number of complex natural systems corresponding to the system “living natural bodies<-»inert natural bodies”, proceeding from such bodies where the living natural bodies build up the bulk of the system; and up to such natural bodies where the inert natural bodies predominate to a corresponding, or even greater degree.

It is also convenient to distinguish the inert natural bodies created by the life process, e.g. sharcoals, diatomites, limestones, oils, asphalts, etc., in whose structure and properties one may establish scientifically the influence of the past stages of life.

[7] One ought to recognize that the living substance of geochemistry is sharply different, logically, from the living substance of the naturalists, especially of many philosophizing naturalists. The living substance of geochemistry is a natural body of the biosphere and represents a set of natural bodies of another order also inherent in the biosphere: a set of *living organisms.* This concept is *entirely,* completely exactly and definitely, based upon scientific observation.

125. Although later I shall return to the significance of the natural body concept for the logic of science in more detail, in this introduction I consider it useful also to emphasize, on this basic object of science (not natural science alone), some features distinguishing the work of scientist from the work of philosopher.

The *philosopher* accepts the word defining a natural body just as a *concept* and makes out of it all the inferences logically resulting from such an analysis.

The systems following from this analysis may be well put together. In them, the philosopher may make profound (although incomplete) conjectures, which reveal something new also for a scientist in the studied object, and the scientist ought to take these conjectures into consideration, for the philosophical analysis had been taking its shape during millenia and does require something more than a natural gift of separate personalities. It requires schooling, erudition, brooding, it even requires the whole life. In some instances, especially in what is tied up with the concepts of reality (Cosmos, time, space, human reason, etc.), a scientist, generally speaking, can not delve so deeply and at the same time with such intelligibility as a philosopher does. On the whole, a scientist lacks time and force necessary for that.

The scientist must use the work of a philosopher, must be in the know of creative and searching philosopher's work, but he ought not to forget its inevitable *incompleteness* and its insufficient accuracy in defining natural bodies in the area of the scientist's competence. He always must correct the philosopher's results, taking into consideration the difference between the real natural bodies studied by the scientist and the concepts on these bodies with which the philosopher works, while, in both cases, the words are the same. In some epochs of the development of science, these corrections may radically alter the philosopher's inferences and to weaken utterly their importance for the naturalist. Just such is the case in our epoch.

A scientist who logically analyses a concept corresponding to a given natural body returns again and again to its scientific objective research in number and measure, as it ought to be for any natural body.

In the course of scientific work, scientists often (thou sands times, during the decades and centuries) return immediately to the revision of the properties of a natural body through measure and weight, through description and elaboration of observation. As a result, the whole idea of a natural body may change radically. Thus, the ideas of naturalists concerning quartz, natural water, or rodents as natural bodies underwent radical changes in the 18th, 19th, and 20th centuries, and the results, obtained in these centuries with a logical correctness, proved to be inaccurate. There are many things that have been "self-evident" in the 19th century and earlier and that will prove to be wrong in our time, and what is "self-evident" in our time, will be found wrong in the 21st century.

We have lived through remarkable changes of this sort that have been tied up with such natural bodies as, for example, space-time or water, owing to the new scientific discoveries.

The philosopher must now make it up with the existence of space-time and not of two mutually independent "natural bodies", space and time. He could not deduce it philosophically in this case, but neither could he *prove* the correctness of his conclusion. Some philosophers came to this conclusion (after all, intuitively) and seemingly influenced scientific thought, but only this thought and research work *proved* the recognition of the reality of space-time as a single universal natural body to be necessary, and scientific thought studying reality still cannot (perhaps according to the essence of things) escape the limits of this universality.

Now it is becoming clear (from all the sum of our exact knowledge) that the inseparability of the space-time is an empirical scientific thesis that have been entered firmly in the scientific work of the 20th century.

Instead of two natural bodies, space and time, we now have a single one. In the late 17th century, the separate existence of space and time had been mathematically substantiated by Newton and led to enormous scientific achievements in the gravitation theory. In the thought of Newton, who had come to this theory, one may clearly see the influence of philosophical and theological ideas. Newton himself attached decisive importance to theology and did not consider space and time to be unbreakably connected. Only now, we have lived through a new deep change, and the system of Cosmos elucidated space-time as an indissoluble whole which seems to comprehend Cosmos in its integrity, but which may be not identical to it.

At this example we see plainly that the natural bodies of reality are heterogeneous with reference to their complexity. The space-time perhaps includes all natural bodies that can be covered by science[8].

126. Let us take another particular example, *water,* for a more specific and definite conception.

Before late 18th century, the concept of water was extremely vague. But only rarely did the observation of nature lead to the doubt, concerning the real existence of water, in cases when this existence became an elementary scientific truth for us. But thus did the matters stand as applied to the concepts of an "absolutely dry body" or "invisible water vapor". The fundamental phenomenon of the penetration of a single natural body—the water equilibrium of the Earth's crust—into all biosphere and perhaps all the Earth's crust has only been discovered recently.[9] Many fantastic or science-like conceptions of natural philosophers and theosophers having lived up to our days and perhaps having in the mass psychology a base for their constant resuscitation, now are fading.

Perhaps the scientific generalization of the water concept still has a residue not uncovered by science and not corresponding to the current research but stimulating it.

In the late 18th century, the quantitative chemical structure of water became determined, and since that time the water concept underwent so sharp a change that any philosophical analysis of water, its *natural-philosophical study,* became something anachronistic. This was a really radical change. It was not a momentous event: due to inertia, fruitless work of the natural philosophers lasted during several generations in the 19th century. Now this work is completely forgotten.

In the Western philosophy, any interest to these questions only faded in the 1830s, when the fantastic creative work of the nat

[8] See: V. I. Vernadsky. ***Problem of time in modern science,*** lzvestiya AN, 7 ser., OMEN, 1932, no. 4, pp. 511-541; V. I. Vernadsky. ***Leprobleme du temps dans la science contemporaine. Suite.*** Revue generale des sciences pures et appliquees. Paris, 1935, vol. 46, no. 7, pp. 208-213; and no. 10, pp. 308-312.

[9] V. I. Vernadsky. ***The water equilibrium of the earth crust.*** Priroda (Nature), 1933, nos. 8-9, pp. 22-27.

ural philosophers began to be too clearly incompatible with the successes of scientific knowledge. Approximately at the same time, or one-two decades later, the scientific water concept became definitely accepted and allowed for by the Indian philosophical thought which was at that time at least at the same, and possibly higher, level as the Western philosophy.

In the 20th century, we live through a new, not less sharp change in the understanding of this natural body, and this change makes us to review radically all our conception of water. In nature and especially in the biosphere, any water was found out to have complex structure: first of all, with relation to the association laws, then to an inevitable electrolytic decomposition of its molecules, themselves owing to the existence of several hydrogens and oxygens[10], maximum in 18 various combinations. If one takes into consideration all the possible associations of molecules and their electrolytic dissociation, one may see that hundreds of *chemically pure waters* exist, each having different structure.

Any attempts at furthering the "philosophical" investigation of water (letting alone the mystical conceptions, which are not taken into account in science, and with every reason) clearly represent an anachronism for a scientist, and this area does not longer belong to the competence of philosophical creativity.

But we still meet the attempts of theosophical search, far both from philosophy and science, although less from philosophy: these are the fruits of ignorance and quest for easier ways for logic of nature than those of science with its thorns and labor.

127. From the above one clearly sees the enormous logical importance of the natural body concept for the scientific work.

This importance is so great that usually the naturalist does not ponder over it.

In reality, for a scientific thinker, all the universe, all the cosmos that may be scientifically constructed, is a natural body in space-time. Scientist can neither work nor think scientifically without this premise.

So far as a scientist works and thinks in his quality of a scientist, there is and can be no doubt for him that the object of scien-

[10] That is, of the isotopes of hydrogen and oxygen. - Edit. note.

tific investigation is real. The single, internally interconnected, scientifically definable cosmos is for the scientist the basic natural body, so far as experience, observation, and logical and mathematical analysis will not prove something other. *Whether the space-time is identical to this cosmos, will be shown by scientific investigation.* So far the area of scientific research does not leave the limits of space-time. But the scientist ought to admit a possibility, i.e. ought to study scientifically, all possible combinations of the identity of the Cosmos, either expressed in the categories of space-time or not coinciding with it. This is a problem still unsolved for the scientific study.

Just in the same way one ought not to look at the problem of the scientifically expressible Cosmos as at the solved problem. Our Earth is a component of the Solar system. The Solar system alongside with millions of similar systems enters as an inalienable part into a certain cosmic island, a certain galaxy. Are the other existing and observable galaxies interconnected? Now we see no logical limitations for the solution of this question.

The man, the biosphere, the Earth's crust, the Earth, the Solar system, its galaxy (the world island of the Sun) are the natural bodies inseparably mutually tied. All of them possess a single space-time, though it is not solved yet whether it embraces all scientifically accessible phenomena, or not.

CHAPTER IX

Biogeochemical manifestation of an impassable boundary between the living and inert bodies of the biosphere.

128. Biogeochemistry introduces into the scientific study of life phenomena a completely new treatment of the natural living bodies, including living organisms, biocenoses, living substances, heterogeneous, homogeneous and complex bioinert natural bodies: soils, silts, etc. This treatment is very different from the usual one, to which biologists got accustomed in their work during millenia.

This treatment bears with itself a new understanding of the living nature which does not contradict to the old understanding but supplements it and makes it more profound.

Considering a living organism under the biospherical aspect, biogeochemistry addresses the atoms that constitute it and are inseparable from the atoms constructing the biosphere. Life manifests itself in the incessant planetary regular migrations of the atoms from the biosphere into living substance and vice versa. Living substance is a set of the organisms living in the biosphere, i.e. of the living natural bodies, and is studied on the planetary scale, for a separate individual, upon which the biologist concentrates, recedes to the background on the scale of all the phenomena studied by biogeochemistry. The migration of the chemical elements corresponding to the living substance of the biosphere is a major planetary process caused mainly by the cosmic energy of the Sun which is building and defining the geochemistry of the biosphere and the regularity of all physical-chemical and geological phenomena basic for the organization of this Earth's envelope.

In the next essay dealing with the biosphere and the noosphere, I shall dwell upon this phenomenon in so far as it is now known to us.

129. When biogeochemistry considers a living organism under its atomic aspect and in its interconnections, it is found out to be a completely different natural body than it is when considered by biology, although a biologist also may study it in its integral combinations: biocenoses, plant communities, herds, forests, meadows, etc.

When biogeochemistry goes down to the atoms of chemical elements, to the isotopes, it penetrates into the phenomena of life under another aspect than biology does: in some relations deeper, but in other ones it loses out of its sight important features of living phenomena advanced by biology.

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. A biologist is nearer to the usual for us and colorful living nature whose part we are. The living nature as studied by biological sciences is nearer to our sensual perceptions than its another more abstract expression studied by the biogeochemistry.

But on the other hand, the biogeochemistry boldly expresses such life manifestations that remain in shadow under the biological approach to life phenomena.

It is best seen in the treatment of the natural bodies, particularly of the taxonomic units (species, subspecies, races, genera, etc.) by either approach.

One may clearly see that all main results of biology (so far as they are based on exact scientific observations and experiments and on logically lawful deductions from them to facts and empirical generalizations) are achievements of science never contradicting to the biogeochemical facts and empirical generalizations established within the same scientific accuracy.

Proceeding from that, it becomes evident that to all the living bodies, corresponding to the taxonomic units of a biologist, biogeochemistry gives a new expression, radically different in its shape from the previous taxonomic expression given by biology, but in its essence identical to that expression.

130. It is most suitable to convey it at a particular example, at some taxonomic division: genus, pure line, subspecies, species, etc.

I shall dwell upon a species.

For a biologist, a *species* is a set of the morphologically homogenous individuals. This notion entirely corresponds (in biogeochemistry) to the *homogeneous specific life substance* of a biochemist.

For a *biologist,* the species is defined by the shape of body, by the histological and anatomical structure, by the physiological functions, the character of coatings, the phenomena of nutrition, reproduction, etc. The main fact is the steadiness of the manifestation of one and the same morpho-physiological structure of the organism through reproduction during geological time. A biologist sees in this steadiness the result of the forces of heredity. The morpho-physiologically accurate description of this stability by a biologist is the base for his taxonomic assertions. Biologists only begin to be seriously interested in the chemical composition of organisms.

Biologists by no means always give numerical data concerning weight, volume, reproduction, size. And when they present them, they interpret them rather *qualitatively* and only now and then, quantitatively. The maximum exact indexes, the middle numerical significance and the numerically expressed ranges of variations, are usually absent.

131. For a *biogeochemist,* a biological species is defined first

of all by the exact numerical values of an average individual, whose set is the *special living substance* coinciding with a biologist's species.

All specific features, as interpreted biogeochemically, ought to be expressed with a quantitative accuracy, through mathematical values, both numerical and geometrical. When one wants to make the geometrical expression of one's results more precise, one must strive for their quantitative manifestation. It seems to me that this is always possible.

Thus, from the biogeochemical viewpoint, a living organism in his entirety ought to be expressed by numbers.

These numbers characterize an *average individual.*

The biogeochemical values defining a species may be of two kinds. Some of them are just the same, that may and must be given also by a biologist. They describe the individual as something morphologically identified. Thus they are expressed sharply at the level of a separate individual.

Essentially, if a biologist would strive systematically for the quantitative expression of the phenomena studied by him, biology would long ago store enough numerical data for biogeochemical inferences.

In reality, this is not the case. In real history of biological knowledge, we see that even for those quantitative features of species which were on the point of the growing interest for biologists, even with reference to these features, the striving for accuracy now died away. For example, the naturalists of the second half of the 18th century rather usually tried and defined the mean weight of animals, especially of vertebrates. In the next century, this striving relaxed. The same, perhaps to a weaker degree, ought to be noted with relation to such an index as the number of individuals emerging in every new generation (number of seeds, eggs, or living youths calculated per individual or pair of individuals).

Now biology does not dispose of a sufficient quantity of data related to this field, neither has it a technique for obtaining them, and the dispersed values have never been collected and are scattered in the ever growing ocean of qualitative descriptions.

One ought not to think that such departure from number and geometrical image essentially tied up with it made the work of a biologist less accurate and profound. Rather even with such departure, this work may go more deep as the work of a biogeochemist. The exact description given by a naturalist-biologist embraces the areas of phenomena where one still ought not to use essentially more abstract expressions of reality. A biologist in his accurate description proceeds from an individual not taking into account how could this description be modified with reference to other individuals. When he passes to them, he inevitably defines the limits within which the given morphological feature changes.

A biogeochemist deals with sets and with the mean (statistical) expressions of phenomena. At this, his main attention is directed towards the mathematical expression of phenomena: the expression through mean values or geometrical images. Thus, the phenomenon is inevitably smoothed over and some individual particularities observed by the biologist are overlooked.

In his desire to express life phenomena proceeding from a living individual, the biologist made the heterogeneity more accurately (qualitatively) known, moved in the deep and came to the limit of the visible to an eye. This limit is the length of the waves of radiance: the wavelength of the ultraviolet, invisible to an eye part of the spectrum.

Taking into account a separate individual, reaffirming in him the studied regularities, and proceeding from the repeated observations (biometrically, to their mean values), biologist can essentially penetrate deeper than a biogeochertiist. He can cover the sides of life phenomena remaining outside the biogeochemical approach to the study of these phenomena. Under such an approach, with the support of the "mean" individuals (§ 129) of biogeochemistry, many important manifestations of an individual are really smoothed away.

But biogeochemistry may approach the lost by it phenomena under another aspect, may obtain a possibility for detecting them with the help of the study on the geological scale. Thus they become manifested, for example, in the process of the transition from the biosphere to the noosphere or in the pre-human stages having preceded the modem noosphere.

132. There can be no contradictions between the biological and biogeochemical descriptions of the living natural bodies if both descriptions have been made correctly.

As it is seen from the above, biogeochemistry supple ments the work of a biologist introducing into the study of life phenomena such life manifestations which had been little (or not at all) touched upon by biologists. The biogeochemical data are far more *abstract* than the concrete and many-sided descriptions of a biologist.

This is a general result of biogeochemical approach to the living nature with a tendency to study it mathematically. For from the mathematical standpoint alone, the study may be limited to some essential features of the phenomenon, while the most part of its qualitative signs stays out as complicating and secondary details.

Biogeochemistry proceeds from atoms building up a living organism and studies their influence upon the geochemistry of the biosphere, upon its atomic structure. From the set of traits of the living organism, biogeochemistiy selects *several ones,* but these traits are just *the most essential* with relation to their expression in the biosphere.

Defining with chemical, geometrical, and physical accuracy all the phenomena of a living organism and the organism itself, biogeochemistry reduces organism to measure and number. Since both are exactly defined, the organism is brought to numerical constants. The number of them is small for every species.

Biogeochemistry defines the living substance (particularly the substance of a given species) by the following numerical constants:

(1) *The mean number of atoms* in an average individual of the species, for all the chemical elements constituting the given living substance. These numbers are obtained through the exact chemical quantitative analysis. One may also express them in percentage of the number of atoms, or of their weight. The number or weight of atoms ought to be related to a mean organism.

(2) *The mean weight of an average individual* is obtained through weighing of a sufficient number of individuals.

(3) *The mean rate of the colonization of the biosphere* by a given organism owing to its reproduction. This parameter of the settlement of the planet can be expressed either in the number of individuals or in the weight of the newly generated descendants per unit of time. This is a very important constant corresponding

to *biogeochemical energy.* Its meaning is tied up with the fact that it connects (numerically) the migration of elements of any species of organisms in its natural life conditions with the planet, the biosphere. At that, referred is the rate of creation of new generations of a given species and the maximum plane (earth's surface) over which this creation can take place.

In this way, a quantity describing the planet's properties and the properties of a given organism becomes tied up with the number characterizing the taxonomic unit.

These three types of values obtained through observation can be easily expressed in the form of numerical characteristic constants.

For the first two cases, it is perfectly clear, and. it is easy to come up to terms with relation to the form of these constants and their numerical expression.

In this case, one is to bear in mind that a biogeochemist studies the sets of organisms in an external environment. For him, the environment is the biosphere with its strictly limited dimensions almost (or completely) unchanging in geological time. Even if they change in geological time, one may admit them unchangeable without any noticeable mistake (for the deviations fade in the medium numbers of the sets, i.e. living substances), with reference to the living organisms as a set whose life is limited by the historical time. In reality, the biosphere is a single whole, a great bioinert natural body, and all biogeochemical phenomena proceed within this body as an environment. The mean number of atoms and the weight of the living homogeneous substance entirely depend on the structure of the biosphere, but the size of the biosphere may be left out of consideration for the given constants, owing to the technique of the obtaining of them. I shall return to this later in more detail.

Through another technique, one may obtain the number for the mean rate of the settlement of the biosphere by some given homogeneous living substance. This index necessarily includes the size of the biosphere.

133. But these three kinds of constants do not answer all biological problems that a biogeochemist must take into consideration and try to express by number, in their integrity.

There is another cardinal phenomenon but little enlightened by scientific work and scientific thought and lacking now a simple and suitable numerical expression. But such an expression is possible, and biogeochemistry cannot do without it.

Here, through a sinuous and complex course of the history of scientific knowledge, biogeochemist approaches a new, scientifically not elaborated region of phenomena far exceeding the range of the clearly defined area of his science.

In this case, as it often is, he must try and create by himself numerical expressions for these new phenomena which he had approached, so concretely in his accurate observation and experimental work. He cannot move further on without beforehand clearing his way.

This is the phenomenon of the *right and left* still remaining not worked out by scientific and philosophical thought. Even, geometrically, this phenomenon is only slightly touched upon. And meanwhile, this is, without any doubt, one of the important geometrical properties of the real space observable in the Cosmos and basic for geometry. However the right and the left are not always observable in geometry. These properties are only inherent in some forms of geometry and are not observed, for example, in the geometries of even dimensions. An exact investigation into the geometry of the right and the left is of an enormous importance for the deepening of the biogeochemical work.

Pasteur[1] in the 1860-80s was the first to comprehend, proceeding from experience and observation, the basic importance of this phenomenon for the biochemical processes, as well as its roots outside of the sphere of life in the cosmic aspect[2]. He advanced one of the manifestations of the left-right phenomenon, the so called dissymmetry[3].

[1] L. Pasteur. *Oeuvre.* Vol. 1. Paris, 1922.

[2] See: V. I. Vernadsky. *Biogeochemical Essays,* 1922-1932. M.-L., 1940, pp. 188-195. Pasteur was far ahead of his time also in the area of crystallography, for he was familiar with the works by Bravais, whose influence on the scientific thought outside France only began in much later times.

[3] Strangely enough, this word had been written down, especially in German literature, by the word “asymmetry”. But asymmetry corresponds to an absence of symmetry (in homogeneous structures, it corresponds the hemihedria of a triclinic system). This nomenclature evidently ought to be abolished for it confuses the scientist. However our special literature still uses it, after the Germans.

Unfortunately this name, very improper, tied up with the crystallographic ideas of the first half of the 19th century, confused the scientific thought, for it did not cover the phenomenon in its whole, as it had been rightly understood by Pasteur and as it did not followed from dissymmetry in its crystallographic definition.

In reality, we deal here with special geometrical and physical properties of the space occupied by the living organisms and their sets, and peculiar (in the biosphere) only to them[4].

Further on I shall use, for exposition of Pasteur's ideas, the term "*state of space*" introduced by P. Curie; however I shall add some nuances. Now one may tell that Pasteur had discovered the existence (for living organisms) of a special space state, distinct from a usual physical-geometrical state of the space. This special space state is the *state of the right- and leftness.* It only exists in the biosphere, with relation to the life phenomena, i.e., in the living and bioinert natural bodies.

In this sense, it is suitable (so far as we speak about the real phenomena) to avoid, when possible, the term "life" and to replace it in biogeochemistry by indicating to the *right-leftness state of living natural bodies,* living substances, and that part of the bioinert natural bodies which consists of the living substances.

134. This permits us to get rid of a huge historically formed heritage of scientific definitions and quests tied up with the philosophical and religious constructions. These constructions penetrate into the scientific biological thought more deeply than into any other area of natural sciences. This is understandable, because we deal with an area of phenomena in which philosophy and religion *side by side with science* still recently dominated, and now retain their position, in every topic. This attached a certain social strength and interest to the scientific work, but still more weakened and distorted the scientific search.

The less the influence of philosophy and religion will be, the more free and productive the scientific thought may proceed in the corresponding area of scientific knowledge.

The main cause of such influence, especially of the influence of philosophy, is the search for the properties of "life" and

4 Pasteur does not tie up the problem with the "right" and "left" of a man.

explanation of these properties. Under such an approach, life as a whole is considered not to be a set of living organisms, living natural bodies, but a special manifestation of *something* which in nature is evident first of all in living organisms, but perhaps exists not only in them.

It seems to me that in admitting life as a special property eventually expressed without any concrete connection with the functions of living organism. Admitting it, one lets on to biology the philosophical and even religious-mystical concepts. Up to now, biology is permeated by the admissions that came to it from outside, no matter whether these admissions be soul, spiritual principle, vital power, entelechy, or vital force. Substituting these special vital properties instead of concrete data of experiment or observation, for living natural bodies—living entities or substances, i.e., sets of living substances—doing so, a biologist (insensibly for himself) introduces into science an enormous stock of concepts having arisen outside of exact knowledge in the huge area of humanities and philosophy.

Certainly—in reality—no naturalist conducting exact investigation ever leaves the limits of the living organism and studies life otherwise than through the structure and properties of a living organism. But when one broadens the concept of life in such way, he ought to take into consideration also another ideas concerning life and its manifestations. Such ideas are contained in the nature-philosophic studies and in the scientific investigations of the spiritualistic, psychological, and parapsychological phenomena. They can be studied on a separate living entity, and therefore one may not take their absence as proved. The scientist working under such conditions and clearly recognizing it, ought to check up on the existence of the above phenomenon. The question may not be answered by logical deductions or historical investigations, but only by accurate experiments and observations. So far, the experience was giving negative results for spiritualistic explanations, but phenomena are being discovered evidencing to the existence of some *properties* of living organisms not registered by the exact knowledge.

This gives a chance for an unjustified interpretation of these achievements as indicating to special properties of *life*. In reality they only indicate to the existence of new properties of *living natural bodies.* The area of scientific knowledge is an area with extremely complex structure, and it is not always easy to separate the results and logical consequences of right observation within this area from pure hypotheses, intuitions, or historical borrowings from the milieu (alien to science) of philosophy or religion, wherein the roots of the related phenomena are situated. The ideas on life not connected, or only indirectly connected, with a living organism or a set of organisms, have a right for existence, especially since the range of the life manifestations of living individuals is utterly great and as all our knowledge is closely tied up with the most deep and strong nervous organization of such a carrier of life as *Homo sapiens.* One ought to distinguish the manifestations of a living organism under two aspects: (**1**) the manifestation of sets of organisms, as in biogeochemistry, and (**2**) the manifestation of separate individuals that may sharply deviate from the mean level. To a considerable degree, it is from the human properties and from the recognition of the life phenomena identity for all living organisms, that an enormous area of the humanities emerged wherein the manifestations of living organisms peculiar to the man only,or almost exclusively to him, are advanced to the foreground.

The phenomena studied by the biogeochemistry only concern sets of organisms, and studying such sets, one never needs exceeding the limits of the phenomena tied up with sets. Here we may identify unreservedly the general property of life (namely of the set of living organisms) as a special state of the space occupied by it.

However, the present biogeochemistry deals with such biosphere manifestations where one human individual may exert a very great influence upon the processes in the biosphere. This occurs just now in the course of the studied here transition of the biosphere into the noosphere. We study the influence of the scientific thought as a geological force, and in this case often the thought and will of a separate person may suddenly change natural processes and manifest itself through this change.

135. In biogeochemistry, the idea of the living substance, i.e. of the set of the living natural bodies, ought to be expressed just as it had been done very long ago for the inert natural bodies: this idea must be built up entirely upon exact numbers. For some inert (for example, astronomical) bodies such measurements had begun mil-

lenia ago. But for chemical and physical properties, for the description of minerals, for geographical phenomena, etc. this had been only done during the past three centuries. Since the late 19th century, the inert natural bodies of the biosphere, including animals and plants, began to be studied quantitatively, and the obtained numbers is permanently growing and is now measured by millions.

In biogeochemistry, such are the weight numbers of living substance, its reproduction indices, biogeochemical energy of colonizing of the Earth, the right- and leftness (expressed quantitatively).

When the idea on the living substance obtained in this way had been compared with the numerically characterized inert (or bioinert) natural bodies of the biosphere, it became clear that (**1**) such a comparison is possible (from a purely logical viewpoint, it had been admitted even before) and (**2**) there exists a sharp, material, energetic difference between the living and inert natural bodies. There is an incessant biogenic exchange of atoms and power between living and inert natural bodies of the biosphere, but with relation to the structure and property, these two groups of natural bodies differ greatly.

This difference is a scientific fact, or rather a scientific generalization. Its result is the negation of the spontaneous generation of living oiganisms from the inert natural bodies under the modem or ever existing during all the geological time, i.e. **2** billion years.

Under the influence of philosophical (but not scientific) considerations, this is not recognized by many scientists, and the concept of abiogenesis is widespread throughout the philosophical and popular scientific literature. The experiments on abiogenesis continue during hundreds of years and up to now

In biogeochemistry, the absence of transition between the living and inert bodies is an *empirical scientific generalization* and not a hypothesis or theoretical construction.

This empirical generalization may be formulated as follows:

There is no transition between the living and inert natural bodies of the biosphere; the boundary between them is sharp and clear during all geological history. In the material—energy relation, in the geometrical structure, a living natural body, a living organism is distinct from an inert natural body. The substance of the biosphere *consists of two states, distinct with reference to matter and energy : the living state and the inert state.*

Materially, the living substance is insignificant in the biosphere; energetically, it is the most important agent in it.

By this a new very significant quality of the biosphere is defined: its geometrical heterogeneity. One may admit, as we shall see in § 138, that the living substance has a non-Euclidean geometry.

136. Before we proceed further, it is necessary to try at an analysis of the main data concerning our understanding of life, and to introduce some new concepts.

I have already talked about the existence of the bioinert natural bodies (§123). Here, we must dwell on them in several words. I have recently said that even the biosphere itself may be viewed upon as a bioinert body.

Essentially, every organism is a bioinert body. Not all his components are living. During his nutrition and respiration some inert bodies get to him. They are quite inalienable of him. Either they get to him as foreign bodies, mechanically, being not necessary for the organism; or their significance is not understood by us. If one calculates the weight and chemical composition of a living organism in the biosphere, one cannot ignore these foreign substances always forming a component of the organism. There is not an organism in the biosphere without them. These substances reflect a kind of biogenic migration of atoms (the main phenomenon studied by biogeochemistry) and therefore must be taken (in mean numbers) into consideration when a set of organisms is analyzed. I shall not rest on this or prove it, but I shall adduce one or two examples. Worms or holothuriae perpetually contain inside their bodies soil or silt whose weight is a noticeable part of their body weight. In the organism, this soil (silt) forthwith undergoes many biochemical reactions. Without such seemingly foreign substances these organisms do not exist in the biosphere for a second: in other words, they cannot live without them. In biogeochemistry, we ought to take these organisms as such that they are, and not purified and freed from these substances that always are present in them.

This is a very ocular demonstration, but in every living organism there are components which, strictly speaking, may not be viewed, upon (taken separately) as living ones in the process of life, in the atomic migrations that support life through an eternally changing equilibrium, through the phenomena of metabolism, respiration, and nutrition. A living organism is always a bioinert natural body. But during the period of life, the living substance dominates in it with relation to mass, not in all cases to volume; such a bioinert body, taken as a whole, clearly manifests its living properties, even when they are not prevalent with reference to volume. For example, vast parts or some organisms are occupied by gas cavities and bladders. Of course, these cavities are not alive but we shall see that geometrically they are something other as compared with inert natural bodies.

Thus a living organism is sharply distinct from the authentic bioinert bodies first of all in relation to the *space* occupied by it, though in its *composition* it its something of a bioinert natural body. Both geometrically and physically, the space occupied by a living organism is distinct from the space of the inert natural bodies of the biosphere. But more than that, any organism is an autarchic system in the biosphere; a system which is a united, self-sufficient, self-defendant one and actively react upon the external and internal environment and upon other living organisms. An animal organism manifests itself within the biosphere as a minor whole alien to it, as a separate little world of its own, as a monade regularly tied up with the external environment. A bioinert body is a more complex system consisting of the living organisms (monades) and inert natural bodies mutually interacting but never intermixing. The overwhelming majority of the natural waters, soil, silts, etc. are the innumerable examples of the bioinert natural bodies.

137. It seems to me that it is high time to take as a starting point for scientific work this energy-matter distinction between the living and inert substance of the biosphere (this distinction has been established by biogeochemistry) and to take into account the scientific results following from this distinction.

In what follows, I shall most briefly note these distinctions which (as we shall see) are far from those in use by the Western biologists and philosophers in their vitalistic-materialistic controversy that lasts for centuries.

These distinctions are not seen and clear when one studies a separate organism, but they manifest themselves as a real phenomenon, as a fact when one takes their sets. They are but poorly seen for a naturalist who studies the individuals, but they are clearly manifested in the living substance of the biosphere.

And it seems to me that they are incompatible with the idea of life as a particular planetary phenomenon. I shall return to it later.

138. *Among these distinctions the most important ones are:*

I. Life on the Earth (existing only in the biosphere) manifests itself in the form of living organisms, i.e. of the living natural bodies with the autarchic volume. There is a life field (both in the environment of the world gravitation and in the microscopic cross-section of the world[5]) where the gravity forces *do not* dominate having not more than a secondary significance.

As it is known[6], the size of a natural body never is an insignificant characteristic. On the contrary, the size may be the most distinctive characteristic within the system of reality. For living organisms, the range of these phenomena is very large: from a size similar to that of the big chemical molecules (approximately $10^{'6}$ cm) to 10^4 cm, for large individuals of plants and animals. The range equals to 10^{10}.

The condition of space (volume) corresponding to the body of a living organism is *dissymmetric,* be that volume great or small. This fact manifests itself in the *rightness* and *leftness*[7], in the inequality of the "clockwise" and "anticlockwise". In the biosphere, this property of space is peculiar to the living organisms alone. Organogenic minerals (oil, coals, humus, etc.) conserve, during geological time intervals, the compounds obtained bio-chemically, wherein the distinction between left and right is clearly expressed. But this property is lost during the geochemical destruction. This state of space in a living organism may well be called Pasteur's dissymmetry[8].

[5] See for example: V. I. Vernadsky. ***Biogeochemical Essays,*** p. 91, 136, etc.

[6] W. Jaeger, ***Lectures on Symmetry*** (and his French articles).

[7] Both manifestations, "rightness" and "leftness", seem to exist, contrary to what Pasteur thought. But it is not proven as yet, it ought to be checked up. See: W. Ludwig. ***Das Recht-Links-Problem in Thierreich,*** Leipzig, 1932. See also the remarks in: V.. Vernadsky. ***Problems of Biogeochemjstry . Issue 1. The Significance of Biogeochemistry for the Condition Biosphere.*** M.-L., 1933, pp. 27-31; V. 1. Vernadsky, ***Biogeochemical Essays,*** pp. 186-193.

[8] See: V. I. Vernadsky. ***Problems of Biogeochemistry.*** - Issue 4. p. 16.

II. The main property of dissymmetry, that is, the *special condition of space—time* answering life and the volume occupied by it, is the fact that the cause and the result of phenomena observed in this volume must correspond to one and the same dissymmetry[9]. In the crystal bodies formed by the organisms and necessary for their life, the dissymmetry expresses itself in the predomination of the left or right isomers. It is possible that Pasteur was right when considered that for the main bodies necessary for life (for proteins and the products of their decomposition[10]) the left isomers are always predominant. This area of phenomena is regrettably little known, and one may expect here, in the nearest time, unexpected and very important discoveries. P. Curie was perfectly right in allowing for the various dissymmetry forms and expressing the geometrical structure or connection manifested in that by the thesis that any *dissymmetric phenomenon is caused by an equally dissymmetric reason.* Proceeding from this principle, which may be called *Curie's principle,* one may conclude that a special state of the life condition possesses a special geometry, and this geometry is not a usual Euclidean geometry[11].

I shall take it as a working hypothesis, before it is theoretically checked. This area of phenomena became in its main traits elucidated in the works by Pasteur[12] in 1860-1880, and P. Curie during the 1890s went profoundly in these phenomena, but a sudden death interrupted in 1906 his life before he was able to relate his achievements[13].

[9] Taking into account that the space states (Curie) displaying dissymmetry (i.e. the violation of symmetry) may be various: for example, the dissymmetry of magnetic field.

[10] *See: V. I. Vernadsky. Biogeochemical Essays. The Study of Life Phenomena and New Physics, p. 175.*

[11] P. Curie. *Oeuvres.* Paris, 1908. Even in crystallography, P. Curie deepened the habitual ideas. Some his corrections to the then (1880) widespread treatment of crystallography were rediscovered and realized by him, although afterwards some other authors had been found out whose works had become foigotten.

[12] *L.Pasteur. Recherches sur la dissymetrie moleculaire des prodyits organiques naturels (Lecons professels a la Societe chimique de Paris le 20 Janvier et le 3 fevri- er I860). Lecons de chimie professees en 1860par M.M.Pasteur, Cahours, Wurts, Berthelot, Sainte-Claire Deville, Barral et Dumas. Paris, 1861, pp. 1-48; L. Pasteur. Oeuvres, vol.l. Paris, 1922, p. 243; V. I. Vernadsky. Biogeochemical essays, pp. 188-195.*

[13] He was crushed by a drayman when crossing a street in Paris, April 19, 1906.

The concept of the “space state” (*etat d’espace*) has been introduced into science in his biography published in 1925[14] by his wife and daughters. Thus he defined, in his family circle, Pasteur’s dissymmetry, during his creative work over this problem (but this work was not fated to be written and published).

III. The Redi’s principle[15] regulating the creation of the organisms in the biosphere is a real and logically correct conclusion out of the principle of Pasteur and Curie. *Omne vivum e vivo* is a manifestation of Pasteur’s dissymmetry, for there is no another way by which the rightness-leftness (corresponding to Pasteur’s dissymmetry) may arise in the biosphere. Essentially, this preservation of life’s duration within all geological time by division, budding, or birth is the main manifestation of the special space-time of the living natural bodies, of the special geometry of this space-time.

IV. The real and logically correct conclusion from the Pasteur-Curie principle is that the phenomena corresponding to life are *irreversible* in time for under Pasteur’s dissymmetry, it is only the space of living organism that can possess only polar vectors, vector of time being one of them[16].

V. In the biosphere, the Redi’s principle expresses itself through the *dissemination* of the organisms owing to the *reproduction*: a phenomenon which is of prime importance in the structure of the biosphere. The dissemination evokes biogenic migration of the atoms in the biosphere and is accompanied by an enormous excretion of free power of the *biogeochemical energy*[17]. This biogeochemical energy reveals itself under the aspect of historical time.

14 As M. Curie put it, this biography was mainly written by his daughter I. Joliot-Curie. It is said there about dissymmetry as a state of space: a definition which is met also in the extracts from Pasteur’s diaiy.

15 See: V. I. Vernadsky. *Geochemical Essays.* Moscow, 1934, pp. 209-210. This principle was first identified by me (as the Redi’s principle) in 1924: V. Vernadsky. *La geochimie.* Paris, 1924.

16 See: V. I. Vernadsky. *The Problem of Time in the Modern Science,* lzvestiya AN SSSR, 7 ser., OMEN, 1932, no. 4, pp. 511-541. (in French: *Le probleme du temps dans la science contemporaine. Suite.* Revue generale des sciences pures et appliquees, 1935, vol. 46, no. 7, pp. 208-213; no. 10, pp.308-312.)

17 The concept that I introduced in 1926-1927. See: V. I. Vernadsky. *On the Reproduction of the Organisms and its Significance in the Mechanics of the Biosphere.* lzvestiya AN, 6 ser., 1926, vol. 20, no. 9, pp. 697-726; no. 12, pp. 1053-1060; V. I. Vernadsky. *Biosphere.* L., 1926; *La biosphere.* Paris, 1929.

The biogenic migrations of the biosphere are clearly distinct from the migration of chemical elements which are not tied up with the living substance. This latter phenomenon becomes only evident (becomes manifested within the mass of the Earth's substance) under the aspect of the geological time.

VI. A very important characteristic is the *maximum* value of reproduction, i.e. of the *biogeochemical energy.* It is conditioned by the magnitude of the atomic complexes (Loschmidt number, first of all, and the maximum velocity of the wavelike movements—''sound"—in the gas atmosphere of the respiration, including the gas content of water).

One of the conclusions is an exceptional significance of the microscopical dispersed living substance and its enormous role in the dispersal of chemical elements in the biosphere. This is tied up with the laws of thermodynamics, with the maximum use of the free energy.

VII. The biogenic migration of elements is for the most part connected with the breath of the organisms and conditioned by the *size and properties of the inert substance of the planet.* Because of this, it has its *limit* tied up (1) with the Loschmidt number defining the number of the molecules in a volume of **1** cm and, consequently, the number of individuals standing in a respiratory metabolism with them; (**2**) reproduction reflects the size of the Earth's surface, and of the biosphere surface.

VIII. The surface accessible to the colonization by organisms is *limited.* As it follows from this fact, a maximum quantity (life mass) of living substance exists which can exist upon our planet. This quantity is constant within geological time, with only minor oscillations.

IX. The most rapid reproduction takes place in the microscopic cross-section of the world, owing to which (see VI about Loschmidt number) the size of the organisms is limited, for the reproduction stands in a reverse proportion to the volume of the organism (E. Sniadecky's rule). Some organisms can exist being smaller than it is defined by this rule: these are the organisms reproducing from time to time (destroying by an explosion the environment of their life—the living organism) and then quickly returning to a latent state.

X. The living organisms possessing metabolism create by themselves their chemical elemental composition constituting their characteristic (and specific) feature that remains unchanged within certain limits. Here, there is an analogy for certain chemical compounds without stoichiometric relations.

XI. In connection with the great biogeochemical energy, we have here millions of natural biogenic bodies—species of the organisms; and still more numerous millions of millions of the chemical compounds, biochemically synthesized in them, in distinction from the inert matter with its 2-3 thousand of minerals and corresponding chemical compounds.

XII. As a result of the radioactive decomposition of the elements and of the biogeochemical energy of biosphere, the biosphere accumulates free energy. With the creation of the noosphere, this process gains great strength (ectropy).

XIII. The living organisms are capable for changing the isotopic mixtures of chemical elements, i.e. the atomic weights of chemical elements within the smallest volumes of the living bodies. The processes of this type seem to take place in another way in the inert natural bodies of the biosphere as well. These phenomena are but little investigated. But one may admit that they are only in these bodies outside of the biosphere and are tied up with the gaseous phenomena in the areas of high pressure. In this relation, the exact definition of the atomic weight of elements in the so formed minerals is necessary.

139. Summing it up, we see that there exists a sharp and impassable frontier between the living natural body of the biosphere with its complexes (living substance) and associations (biocenoses and bioinert bodies) and the inert natural bodies of the biosphere: minerals, crystals, rocks, etc., in their innumerable variety.

This is neither a theory nor a philosophical or scientific hypothesis, this is an *empirical generalization* from an innumerable set of exactly established logical and empirical facts which may only be put into doubt on the base of the critique of these facts or setting off against them other empirical generalizations which contradict one or another items of the preceding § 138.

They cannot be refuted logically or philosophically. They relate to a certain natural body, living organism.

All the generalizations indicated here do not transcend the phenomena that may be observed in the life of the organisms and their complexes. These generalizations 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.

They answer the logically understood concepts of biogeochemistry. But in the area of logical thought in its contemporary literary expression, they frequently contradict the current ideas predominating in the thinking relating the life phenomena.

When the philosophical ideas oppose these empirical generalizations, one may let them (philosophic generalizations) alone and estimate them logically as *philosophic fictions.* For the philosophic ideas are based on the analysis of general *concepts* which are far from always and completely covering the scientific facts and scientific empirical generalizations that substantiate them. In this connection, all the problems interesting (for example) for vitalists and materialists, be they scientists or philosophers, exceed the limits of our consideration and we do not really meet them in the area studied by us.

In the phenomena studied by biogeochemistry, life exists in the natural living bodies and almost exclusively in them. It is only in the problem of noosphere that we are to reckon with the factors, strictly speaking, not covered by the usual ideas on the living natural bodies. But in biogeochemistry, these factors may only be studied within the limits of the living natural bodies.

140. Biology deals with life at a large scale. It is logical and right to pose here a question whether life manifests itself in the biological processes which may infringe upon the inferences made on the base of studying the living natural bodies.

In the course of time, the closest connection between biogeochemistry and biology must only increase. Therefore this question also arises in biogeochemistry. The further analysis of the noosphere is only beginning. With this analysis, this question will be formulated even more profoundly and clearly.

An enormous, even perhaps main, part for biology plays a phenomenon answering the properties of the highest forms of the human life. If one takes the term of “natural phenomena” in its larger sense, these forms also include the social and spiritual manifestations of man which cannot be severed from the biological foundations of the human organism. It is here that we are to reckon with the great influence of the enormous cultural heritage tied up with the past. A biologist is inseparably connected with this philosophical, religious, and social heritage. He cannot get rid of this heritage ultimately, even if he strives for this goal.

In this relation, a biogeochemist is in an evidently different position. In his problematics, he is limited, from one hand, to the processes which are reflected in the natural living bodies; and from another hand, to the processes depending on the properties of chemical elements, their mixtures and isotopes, i.e. on the properties of the atoms. Still for a biogeochemist (in the picture of the noosphere that had been discovered before him), the biogeochemical manifestation of the highest properties of a living organism now first begins to be an object of his competence. It is the same highest property of a living organism which play such a great part in biology and philosophy.

Also for a biogeochemist, a question arises here, do we deal with new manifestations of the life phenomena which are not covered by the categories of the facts expressed by the constants of the living substance? Or we deal here essentially with the same phenomena which are biogeochemically expressed in a weaker degree in all living substances studied by biogeochemistry? In the noosphere, the real influence of the human reason in the history of the planet, becomes manifested clearly under the biogeochemical aspect.

The human reason is the main object of the philosophical thought and is far less investigated when compared with all other biological manifestations on our planet. But in the course of this study, a biogeochemist never leaves (in the noosphere) the bounds of the living and bioinert natural bodies. Therefore he may leave out all philosophical and scientific hypotheses and theories tied up with the understanding of the spiritual sides of human thought. Whether the inferences of these theories and hypotheses concerning the human spiritual life be such or another, the inferences of the biogeochemist do not change in the least.

The main question arisen in this connection is whether the human reason (including in this ease all spiritual manifestations of man) is something new, even peculiar to the highest vertebrates or even to man; or it is a property of all the natural living bodies? One or another answer to this question cannot have any significance in biogeochemistry, for a decisive and determining factor for the noosphere is the spiritual life of a human personality in its special manifestation.

141. A biologist is in a completely different position. He ought to work in the area of the complex spiritual environment created during the centuries by philosophical, religious, and social thought meeting at every step ready concepts which are contradicting, often created by the poetical and artistic intuition, and based upon the most intimate manifestations of a human personality.

A biologist, at the present state of science, cannot understand all these questions and solve them. But it seems to me that he can minimize the harmful influence of his spiritual environment by resorting to a severe and cautious relation to its pressure and to more strict definition of life.

For in reality, biologist (like biogeochemist) studies the living substance (in the above sense) and not life. He identifies separate living natural bodies: living organisms. If a *living organism* (and its totality—*living substance)* is identical, for biologist's research, with *life* concept, then it is more suitable to proceed also in biology from the concept of the living natural body, i.e. of the living organism, and not from the concept of life. It is more suitable for the purpose of freeing science from the philosophical and theological concepts which are alien to it.

Whether there exist manifestations of life apart from living organisms, it may be irrelevant for a modem biologist, for all his work lies in the area of investigating living and dead *organisms.* They are really what he calls life. For a philosopher and theologist, life perhaps is not one and the same with a living organism and its totality.

Still a biologist or a biogeochemist may not reckon with the existence of better understanding of life: an understanding different to that which is basic for them and which has been for centuries in a contact with the area studied by them. They meet it at every step and ought to be on the alert, not to be embraced by its influence. They must be in the know of these different ideas and estimate their possible and admissible significance in the work that they fulfill.

142. Before passing to this theme, I think it useful to put together the items of the § 130 and to represent them in a new form: in the form of the *distinction between the living and inert natural bodies in their biospheric manifestations.*

Here is this summary.

The inert natural bodies.	*Living natural bodies*
I. The inert part of the biosphere does not contain bodies analogous to the living natural bodies. The disperse inert substance is concentrated in the biosphere. In the deeper parts of the planet, it is choked by the pressure. This substance is created either by the death of the living substance or by the influence on the biosphere of the moving gaseous or liquid phases which always are bioinert bodies.	The living natural bodies, only show themselves in the biosphere, and only in the form of the discrete bodies: living organisms and their complexes; at the macroscopic (gravitation field) and the microscopic levels of reality,
II. In the inert natural bodies, there is no manifestations of the rightness and leftness that would not follow the laws of symmetry for solid bodies. Therefore, when rightness and leftness appear in the homogeneous anisotropic space of the crystalline state of a solid body *{geometrically* special but expressed in terms of Euclidean geometry), they do not violate the symmetry laws, and there is no marked manifestation of dissymmetry. Dissymmetry in the biosphere only can form out of the dissymmetric environment, by *birth* (Curie's principle).	The rightness-leftness characterizes the state of the space occupied by the body of a living organism and its manifestations in the milieu that surrounds the organism. In solid substance of the living organisms, the dissymmetry manifests itself. The same dissymmetry reveals itself in the dispersed particles of the colloidal environments which are part of the living substance, The symmetry laws of the solid crystalline structure are violated.
III. A new inert natural body is always created by physical-chemical and geological processes, without any reference to the earlier natural bodies, whether live or inert. The processes of its creation may also take place in the living bodies and change in their manifestations, producing the bioinert natural bodies inculcated in a living natural body.	A new natural body, a living organism, maj, be *born* from another living organism. There is no abiogenesis in the biosphere. There is also no sign of it in the past geological epochs, During generations and generations, one living organism is bom from another (essentially similar) organism (Redi's principle). In geological time, processes at the base of the laws still

ical and geological processes which can be synthetically reconstructed by experiments.

reproduction, i.e. by the creation of a new living body out of a preceding living natural body, and so generations in, generations out. Any living natural body is created by a complex biochemical process without leaving its own state of space.

IV. The number of the inert natural bod- The number of the living natural bodies does not depend on the size of the

ies is tied up (quantitatively) with the size of a certain Earth's envelope, the biosphere. A scientific working hypothesis is admissible (and is to be checked) about the cosmic metabolism of the living natural bodies.

planet, but is defined by the properties of the planetary matter energy. The biosphere is incessantly receiving and returning back the matter-energy into the outer space. There exists a continuous material-energetic exchange between the Earth and the cosmic space.

V. The area and thevolume of the The mass of the living substance (the

manifestation of the inert natural bodies are not defined within the limits of a planet and their mass varies with geological time.

complex of all living natural bodies) is near to its limit and perhaps remains dynamically constant during geological time. This mass is defined, in the last, by the quantity and oscillations of the radial solar energy embracing the biosphere.

VI. The minimum size of an inert natural body is determined by the dispersivity of the matter-energy (atom, electron, corpuscule, neutron, etc.). The maximum size is determined by the size of the planet which may be itself considered as a bioinert natural body. Under the aspect of our exposition, this size is defined by the volume of the biosphere which represents a special bioinert natural body. The size varies enormously (in the range of about 10^{22}).

The minimum size of a living natural body is defined by respiration, mainly by the biogenic migration of the atoms, in accordance with Sniadecki's princi-pie and Loschmidt number. According to the observations during geological time, the maximum size of the living natural body does not exceed hundreds meter, both for animals and plants, This may well depend upon some deep causes that define the possibility of the existence (in the biosphere as a bioinert natural body) of the states of space answering a living natural body. The oscillations range is 10^{10}.

VII. Chemical composition of the inert natural bodies is entirely a function of the composition of the environment within which these bodies are created.

Chemical composition of the living natural bodies is created by *themselves* out of the environment from which they select (by nutrition and respiration) the

One may express it so: this composition is defined by the "game" of the physical-chemical and geological processes at a geological scale.

chemical elements necessary for life and reproduction: for the creation of the new living natural bodies. In that they perhaps may change the composition of their isotopes, may alter their atomic weights. The overwhelming part of their chemical composition is created by them in the form of independent (to a certain degree) bodies in the biosphere, i. e. in the bioinert natural body of the planet.

VIII. The number of various chemical compounds (molecules and crystals) in the inert natural bodies of the Earth's crust , therefore in the biosphere, is *limited.* There exists *a few thousand* of the natural earthly (probably also cosmic) chemical compounds; molecules and crystalline spatial lattices. This explains the limitation of the number of species of the inert natural bodies in the biosphere as well as of its bioinert natural bodies.

The number of the chemical compounds in the living natural bodies and the quantity of the living natural bodies for which these compounds are specific, are *innumerable.* We already know *millions* of species of organisms and *millions of millions* of molecules and crystalline lattices which correspond to these species.

IX. All natural processes in the domain of the natural inert bodies, except the radioactivity phenomena, *decrease* the free energy of the environment (these processes are reversible). In this case, the free energy of the environment is the free energy in the biosphere.

The natural processes of the living substance having been manifested in the biosphere *increase* the free energy of the biosphere.

X. The isotopic mixtures (the Earth's chemical compounds) do not change in the inert natural bodies of the biosphere. The only exception is radioactive decomposition. There seem to exist natural processes outside the biosphere (e.g. movements of gases under high pressure) which disturb the established isotopic mixture. But on the other hand, the study of chemical composition of the meteorites, i.e. of the Galaxy substance, indicates that they have the same isotopic relations as the Earth's elements do. The constancy of atomic weights is only established in the first approximation and it is possible that more sensitive methods will discover some actually existing deviations.

The change of the isotopic relations is perhaps a property specific for the living substance. It is proved with reference to hydrogen and potassium. This phenomenon urgently needs a proper study. For it is tied up with the energy expense, a distinct delay in the output of chemical elements out of the biogenic migration expected theoretically is observed in reality in the migration of chemical elements of the living substance. It was first observed by K. von Baer with reference to nitrogen,

CHAPTER X

Biological sciences ought to be placed equal with the physical and chemical ones among the sciences studying the noosphere

143. From the preceding essay, it is completely clear and scientifically indubitable that there is an impassable frontier in the biosphere between a living natural body and an inert or bioinert natural body. This frontier is revealed in exactly stated and irrefutable phenomena of a great scale and importance. These phenomena far exceed the limits of life and are closely tied up with the structure of the regular Earth's envelope—biosphere, are characteristic of this structure.

Life sciences in the system of scientific knowledge

The matter-energy distinctions between these groups of natural bodies, as mutually compared in the preceding § 142, present a mere exposition of facts and the empirical generalizations strictly deduced from them. There are no hypotheses and theories, even if scientific ones, in this comparison. It follows, logically and irrefutably, that biologists ought to reckon with this inference and may not merely let it out.

In reality it is not so. One may even assert (as it seems to me) that usually all the mass work in scientific biology sharply contradicts ideologically this great natural phenomenon. The biologists neglect and ignore it. Its importance is first elucidated clearly and distinctly by biogeochemistry as a branch of biological sciences.

In this key question of biology, the question of the distinction between the living and dead, biology has a multi-millennial history having created solid traditions and working skills in it, sharply distinguishing biological sciences from the other branches of exact natural science. It seems to me that here, under somewhat distorted form, the same distinction between living and inert bodies manifests itself that has been considered in § 142.

Even today, the biological sciences are entirely embraced and penetrated by the ideas and thought habits essentially alien to the exact natural science, as far as one deals with the current scientific work and thought. Historically, biology was first based upon the religions ideas, then upon the religions and philosophical ideas at once, at last upon philosophy solely, and that to such degree and under such aspect in which this status has long been overcome and forgot in the **20**th century in all concrete sciences on inert nature.

Biology is still dominated and penetrated by philosophical ideas. It is partly a result of the specifics of its research area. Biology covers under its competence all problems and sciences concerning *man.* Therefore biologists inevitably are in another position as compared with the researchers of the inert nature. In biology, man is simultaneously the subject and the object of research. In biologist's thought, man inevitably occupies the first place and gives a standard for the comparison of life phenomena. Owing to that, the phenomena which are essentially secondary in the environment (and before the transition of the biosphere into the noosphere also in the nature as a whole) occupy the first place in biological investigation, namely the phenomena tied up with human spiritual activities. In all the area of the humanities (including psychology), the religious and philosophical thought habits are all-penetrating, often dominating, and so do their formalizations coexisting with the scientific understanding of nature. Also biologist's scientific work not tied up immediately with man (but based upon humanities) becomes connected with philosophy to a higher degree than sciences in inert nature are, for human spiritual life may be represented as the highest expression of all the living things which are inseparable from it. The living organisms, from bacteria to higher plants and higher animals, including man, has been represented as a single united whole: as matter penetrated by *life.* In biology, life (instead of the living natural bodies as in biogeo-chemistry) now occupies the first place.

To explain *life* and to understand *its* concrete manifestation in the living nature that consists entirely of the living natural bodies, a biologist must seek for support, under such an approach to the problem of living, aside with the concept of "life", in the religious and philosophical quest which for centuries has been only oriented to life. In this quest, biologists has come to a completely different (as compared with the § 142) idea on the difference between the living and the inert.

To make out the existing contradiction, one must shortly dwell on the philosophical background of biology.

144.1 shall only rest on such philosophical searches which are reflected (as such and consciously) in biologists' research. I let alone all philosophical ideas devoid of living representatives, which would somewhat conspicuously influence the current biological thought in its mass manifestations. Under such aspect, two major philosophical trends may be recognized, each with its own history that has been lasted for millenia.

One may easily understand the influence of materialism, in its many manifestations, upon the research natural-scientific work. This influence is even inevitable, for the materialist philosophy is a trend within the *realism,* i.e. the common base of science and philosophy in the study of the external world problems. A naturalist proceeds, in this work, from the reality of the external world and studies it only within the limits of this reality.

In the first half of the 19th century, beside scientific work.

the natural philosophic work went on (as a parallel and equal with scientific work) in the area of the descriptive natural science, particularly in biological science.

This explains the enormous influence exerted, in the course of history, upon the biological thought by the idealist philosophical search. This is tied up with the great philosophical movement that lent to the West European, especially German, philosophy of the late 18th and the early 19th century, its world importance in the history of human thought. This influence, through its unoriginal followers, is clearly felt even now.

It was only in the middle of the 19th century, that the insufficiently deep (philosophically) materialist ideas became prominent in Germany, in the connection with the scientific-philosophical work of Karl Marx and Friedrich Engels. With this work, these ideas entered the circle of the influence of the Hegelian philosophy. In this new form and radically altered, they received, after the October revolution, the state support as the official philosophy in our country. And here, because of the lack of the freedom for philosophical search, they exert great influence upon biological research. But this influence is merely superficial, one may even say, officially formal. In this philosophical movement, no somewhat original thinker has appeared yet, and there is no benefits (as seen in research results) for the creative biological scientific thought. To estimate correctly the real significance of this complex and hegelianized form of the materialist world outlook for the world biological research work, it is sufficient to look into its manifestations in the countries where the freedom of philosophical thought exists. There, this materialist trend with its interpretations is lost among innumerable new philosophical quests as mirrored in the biological sciences. In our ideological milieu, this trend with its manifestation in the area of biological problems is a hothouse plant whose roots do not go in the deep.

145. Taken as a whole, the influence of the philosophical thought is far more reflected, in our time, in the biological problems receiving a non-materialistic interpretation.

Here we meet, a revision (under the philosophical aspect) of the modem significance of philosophy in the research work: we meet, on the one hand, the philosophical scepticism, and on the other hand, the attempts at new philosophical creative rebuilding the philosophy under the influence of the mighty scientific movements of the **20**th century. The new forms of the realistic philosophy become created. Some of them seem to deserve serious attention of the naturalists.

The skeptical forms of the philosophical thought proceed from the primacy of science in its area over philosophy and religion. Their adherents recognize that (in the area dominated by the research work) the importance of philosophy is mainly tied up with the analysis of scientific concepts using the multi-centennial work of philosophical thought in its historical manifestations. But there remain the knowledge areas where science does not have a strong foothold, or which perhaps are unapproachable to the science at all. One may admit the existence of such areas in philosophical relation. But their philosophical inferences are not obligatory for science, and it may not reckon with them if they contradict scientifically established facts and the scientific empirical generalizations logically deduced from them.

Science is inseparable from philosophy and cannot develop in its absence. It may be non-contradictory to the foundations of philosophy (even not saying about skeptical philosophies) in its realistic systems, i.e. in those recognizing the facts exactly established by science as real indubitable facts. The realistic systems cannot contradict facts: such is the case, for example, for a series of the new Indian philosophies. At the same time, science cannot go so deep into the analysis of concepts. In creating them, philosophy leans upon the analysis of the reason as well as on the scientific research as such.

Among the numerous philosophical systems of our time created with an increasing clarity under the influence of scientific knowledge, there are a series of philosophies-precursors of the future heyday of philosophy. A contemporary scientist cannot work without paying attention to them. Among them, biologists must now take into account the *holistic philosophy* [1]. In its foundations, this philosophy is essentially based upon the analysis of the same natural bodies that substantiate the biogeochemical work. It seems to me that this (or another, similar to it) system will at last wind up the fruitless polemics between the mechanicists and vitalists. This polemics is rather scholastic; it has been introduced into biology by the philosophers and does not issue from the observed facts. The holis

' J. Smuts. *Holism and Evolution.* 2 ed. London, 1927.

tic philosophy is also interesting because it tries and reconstructs the cognition theory having deeply rooted, during the past century, in the scientific thought of physicists and mathematicians. Before the holistic theory in the **20**th century became transformed into talmudism and scolastics, it managed to make some basic scientific concepts more precise. Being abstract from the particular real facts and owing to the deep analysis of the general cognitive problems (this analysis leads to the basic dubious and uncertain philosophical, logical, and psychological constructions), the cognition theory only found a suitable soil among the mathematicians and theoretical physicists. In other areas of natural science, it is mainly used (without any tangible scientific results) by the philosophers and scientists with a philosophical bias to the so called *scientific philosophy,* which essentially stands apart from the living scientific work.

The philosophy of holism with its new understanding of the living organism as a single whole in the biosphere (i.e. as a natural and self-dependently manifesting living body) seems to be the first philosophy that tries and gives a new shape to the cognition theory. Before our time, this philosophy was neglected by the naturalists—observers of the real biosphere, ever running into the real natural bodies and tens of thousand separate facts to be understood and kept in memory. Now we deal with a curious philosophical trend of an eventually great importance for a particular problem concerning the impassable border between the living and inert natural bodies of the biosphere, i.e. between the living and the dead in their real scientific manifestation.

This is not the only philosophical trend that is relevant here. Perhaps, some interesting approaches are revealed by the philosophy of Whitehead.[2]

Some echoes of the new Indian philosophical thought also may deserve attention.

In the nearest future new scientifically admissible trails may be blazed learning to the philosophical analysis of the main biological concepts.

146. Taking into account the contemporary state of biology and its inseparable connection with philosophy, I try here to reduce to six theses the relation between the living and the dead

[2] A. N. Whitehead. *Process and Reality.* Cambridge, 1929.

(i.e. scientifically: only the relation between the living and inert natural bodies of the biosphere) that dominates now the research work of the biologists. These theses only give a general picture of the mass scientific work and do not concern solitary scientists standing outside the main current of biological work.

One may take it for granted:

1. There are no exact scientific data proving the existence, in the living, of special *life forces* peculiar solely to the living. Even as a scientific hypothesis (and to that, only concerning the individuals constituting the living substance) these ideas, formerly dominating science, are now almost anachronistic.

2. There are another ideas that explain the essence of life and the distinction between the living organisms and the inert natural bodies as a special life energy, entelechy, monades, clan vitale, etc.; these ideas emerge from time to time and essentially are figurative expressions of the living forces, the ephemeral creations of reason, never having led to any scientifically important discoveries or generalizations in the past.

3. In the middle 19th century, the "living forces" in the scientific biological work of a physician or a naturalist vanished finally. And they could not be replaced, for this purpose, by their ideological imitators (as named in the preceding item). Letting aside all these natural-philosophical explanations, the naturalist-biologists in overwhelming numbers passed to the investigation of living nature independent of its living specifics, i.e. to its investigation as a *nature indiscernible from the inert nature under the material-energetic aspect.* In part, they proceeded from the materialistic philosophical ideas denying any essential difference between the living and dead nature: in the last end, all biological phenomena will be explained completely by the physical and chemical processes, just as all phenomena of the inert matter are. But these scientists were joined by the naturalists-biologists alien to this philosophical premise (belief, as a matter of fact); they thought that following this way, either they will meet new phenomena that will make them to reject this hypothesis, or it will be proved as a true one.

4. Now one may see that in the end, as a result of the worldwide, almost centennial work., biologists did not obtain any indications that now, in 1938, permit to assert that they are nearer to the solution of the problem than they were in 1838. Really, they did formulate the philosophical question about the life forces and their analogues, but for answering this question, the biologists only applied the scientific experiences and observations that were accessible to them. But they proceeded from a philosophical hypothesis and not from a scientific one, and *since this hypothesis was false,* their scientific experiences and observations had been placed in the conditions least favorable for finding the answer. For in this way, all attention became oriented to the search for the *common traits* between the living and the inert (in accordance with the initial philosophical premise) rather than to the search for *differences.* In a huge non-studied area of phenomena. An unlimited number of scientific facts always becomes discovered in the vast field of unknown phenomena, that often are very interesting and require scientific investigation. The available scientific research forces are inevitably limited. Not having the possibility to estimate at once the importance of the newly discovered facts and realizing their scientific interest, the researcher unavoidably directs his work to finding out the common traits (in reality, may only choose this research direction). Under such a character of scientific work, one may miss the distinction between the living and the inert. As we have seen in § 142, this distinction became really missed by the biologists. The phenomena listed in § 142 proved out to be almost ignored from the biologist's viewpoint.

5. Proceeding from the same concept of the identity manifested under the final deepening of the research into the "living-inert" problem, the biologists pose also another problem that has led to an enormous work and incited the thought to a wrong way. Up to now, this work remains fruitless.

This is the problem of the spontaneous generation of the living organisms out of the inert matter. The great majority of biologists, proceeding from the materialistic philosophical ideas, or from the scientific hypothesis of an eventual identity of the living and the inert, believe in an inevitable existence of the spontaneous generation. And the idea about abiogenesis taking place at every step in the biosphere that surrounds us is widely spread.[3] Other biologists think that abio-

[3] I remember my conversation with an eminent naturalist, academician I. P. Borodin, after my reports in the Leningrad Society of Naturalists, whose chairman Borodin was. I .P. thought that abiogenesis still probably exists, and perhaps constantly, in the world of the lowest organisms invisible to the eye. I. P. Borodin, an outstanding naturalist, never was a materialist under any philosophical or religions aspect. As to the philosophical materialists, for them abiogenesis is one of the articles of their faith.

genesis took place in one of the epochs of the geological history of our planet. In this last case, one cannot deny it, as we saw it in § 142, but it needs such environmental conditions which we see as possible but essentially inconceivable. These conditions have created a special state of space on the Earth which distinguishes the space of the body of a living organism from that of inert natural bodies.[4] Now there is no such space in the biosphere outside of the living organisms.

6. During the past years, a new phenomenon has been discovered in the biosphere: the existence of the living organisms or their stages invisible for our eye even with the help of the most strong microscopes in the ultraviolet range. These organisms have the same order of size as the molecules, i.e. the order of 10^{-6} cm. This is the phenomenon of *viruses,* which seem to play a great part in the vital processes of the biosphere. Viruses can reproduce themselves. Their agglomerations are visible microscopically. The viruses are the cause of the most various diseases of the plant and animal organisms. Their latent forms have been found in the bioinert matter of the biosphere: in soils, troposphere, natural waters. There hardly is any doubt that they may also be found in the hydrosphere: in the sea water and in the sea organisms. In 1939, Stanley identified them as uniform chemical bodies, the proteins of a certain chemical formula and a definite size of molecule.[5] These Stanley's observations have been checked up and proved. Other protein bodies have been found obtained in the form of "crystals" and also having a certain chemical formula.

If these phenomena would be ascertained in the form described by the biologists and biochemists, we would have the "living proteins" whose existence was admitted by a number of biologists[6]. This was for them the reason to hold abiogenesis for possible. Of course, every chemist would join their viewpoint under the named properties of viruses. But we must make the inference more precise:

4 L. Pasteur. *Oeuvres,* vol. 1. Paris, 1922. One usually does not remember that Pasteur admitted abiogenesis and worked with this problem experimentally.

5 W. M. Stanley and H. Loring. *Properties of Purified Viruses.* Relazioni del IV Congresso Internazionale di patologia comparata. Roma, 15-20 maggio. Roma, 1939.

6 See a curious historical review of H. Grasset, a pioneer of abiogenesis: H. Grasset. *Etude Historique et Critique sur les Generations Spontanees et l'Heterogenie.* Paris, 1913.

still, it is only certain that these viruses—protein molecules—have been as yet observed only as generated inside living organisms, i.e. in the special state of space that corresponds to the living organisms.

But the problem is not so simple. Stanley and other authors after him have obtained the proteins—viruses, by means of crystallization with the ammonium sulphate, but they did not prove (**1**) that this is a real crystal, i.e. three-dimensional anisotropic *homogeneous* bodies, and (**2**) that these crystals are free from viruses.

It is known that the crystals of the proteinic bodies possess special properties: in particular, they swell in the liquids and the conditions of their growth still remain ignored. One cannot consider the
reiterated recrystallization of a protein into $(NH\mathbf{4})\ \mathbf{2}\ S0_{\mathbf{4}}$ to be a proof for the homogeneity of this protein. When the proteinic crystals swell and when they grow by intussusception, the smallest viruses cannot be isolated even through **10**-fold crystallization, as it was done by Stanley. But beside that, the conclusion about the crystalline structure of these proteins was made solely proceeding from a mere microscopic observation of their external form. This is no proof.

Before the year 1936, we had no observations at all that would prove the homogeneity of the proteinic crystals and their three-dimensional anisotropy. There were no crystallographic measurements of the proteins. Under such conditions, it was fully admissible that in the proteinic crystals incorporating viruses we deal with liquid or mesomorphic bodies. And if it so, these proteins always include invisible viruses, i.e. there exist no living proteins.

In the past year, several important papers have been published which permit to state it with more certainty. Independently from one another, Bernal and especially Bawden with the coauthors[7] proved that the crystalline proteins of Stanley and others are not crystals (when studied by X-rays) but are either liquids or solid mesomorphic structures. They do not possess the properties of homogeneous three-dimensional anisotropic structures. At the same time, the works by Bernal and his co-authors[8] have proved

[7] F. C. Bawden, N. W. Pirie. J. D. Bernal, F. Fankuchen. *Liquid Crystalline Substances from Virus-Infected Plant.* Nature, 1936, vol. 138, no. 3505, pp. 1051-1052.

[8] J. D. Bernal, F. Fankuchen. *Structure Types of Protein "Crystals" from Virus- Infected Plants.* Nature, 1937, vol. 139, no. 3526, p. 923-924.

the homogeneous anisotropic structure completely answering the crystals for haemoglobin and a series of proteins. The new precise technology has permitted (for the first time, as applied to the proteinic crystals) to numerically express the elements of the crystals over a spatial lattice. Such expression proved to be impossible for the proteins having the viral properties. The question of the existence of the living proteins seems not to arise in that form any more, under a closer checking. However, they may be called (without any contradiction to facts) proteins containing the living, perhaps latent, viruses. Neither the crystalline liquid nor solid isomorphic body can be isolated by "recrystallization" from the smallest viruses about 10^{-6} cm in size, even if this recrystallization be iterated as it was thought sufficient for defining the proteins that included the filterable viruses. There is are no crystallization flows (which would influence the crystallization even of the smallest bodies 10^{-7} cm in size and this way purify the crystallized substances) under the forming of these mesomorphic or liquid "crystals".

147. Here, it would perhaps be useful to remind, from the archive of science, of the works of a half-forgotten researcher, A. Bechamp (1816—1908)[9]. The fate of this researcher is very special. We shall further see that he is a direct predecessor and rival of Pasteur in discovering the main manifestations of the living organisms. But all attempts of Bechamp to attract attention to the importance of his works and his critique of Pasteur did not found any response. He lived up to almost 100 years, having outlived Pasteur by 13 years (he was **6** years older than Pasteur). Before his death in 1905, Bechamp published a memoir, not fully impartial but deserving serious attention. This memoir was devoted to Pasteur's work.[10] After Bechamp's death, the importance of his work on this and a series of other problems begins now to be elucidated.[11]

[9] See about A. Bechamp: V. I. Vernadsky. ***Ocherki geochimii.*** M., 1934, p. 329. Already in the year of Bechamp's death, an American physician, Leverson, began an attempt at rehabilitating Bechamp. See: E. D. Hume. ***Life's primal architects. (An essay on the bacteriological work of Antoine Bechamp).*** (Reprinted from "The Forum". - London, 1915). E. D. Hume. ***Bechamp or Pasteur? A lost chapter in the history of biology. Found on MS, by M.R.Leverson***, London, 1932, Quermonpress.

[10] ***A. Bechamp. Les grands problemes medicaux. Paris, 1905.***

[11] See a general review: E. D. Hume. ***Op.cit.***

Bechamp was a forerunner of the scientists who have established the concept of "virus" as an invisible living body having a size of a molecule. He thought that these smallest bodies penetrate into all organisms and play there a great part. Just as the cell in which they live, the viruses exist during an uncertain time and became only annihilated under the influence of external causes. He called them microzymes and presented their chemical analysis. And the interest of his work consists in the fact that he attracted the attention to the biosphere and tried to prove that the viruses are widely spread in the soil, in the sedimentary and organogenic rocks, as well as in the sea water.[12]

Bechamp's works in this direction deserve attention, deserve to be repeated and tested with the new techniques with an exactness incomparable to those used by Bechamp; and in the new circumstances created by the discovery of the filtrable viruses.[13]

148. The failure of reproducing the abiogenesis led many biologists, recognizing the unity of life and the scale of the processes in the biosphere corresponding to life, to the search of another version of its origin on our planet, namely, its being brought from the cosmic space. This failure became evident after incessant and continuous attempts at obtaining a living organism abiogenetically, and after the critique of these attempts pronounced essentially at the base of the sound empiricism. As Pasteur noted, the abiogenesis is only thinkable in a dissymmetric environment. Such an environment does not exist outside the limits of the living organisms at our planet. The organogenic substance of the biosphere has not such state of space , while this substance retains some properties of the space state corresponding to life. This substance only contains the inert matter in which the past life broke the balance between the right and the left. When an organism dies and turns into inert substance, the cause of this disbalance (which is the manifestation of life) disappears. The

[12] Perhaps the viruses contain metals, if one is to believe the analyses of the elements migration made by Bechamp. See: A. Bechamp, in the journal: Annales de chemie de physiologie. The correctness of these analyses still remains to be proved.

[13] A.Bechamps, ibid. Now approximation to his views becomes achieved in the attempts of solving a topical but unclear question about the conservation of latent life during an uncertain, geologically long period.

attempts at abiogenesis, made also in such bioinert environment, gave so far only negative results.[14]

As it follows from § 142, one can not deny the existence of such environment in other geological epochs. And the admission of such phenomenon does not contradict the biological ideas. But we have no positive geological evidence of the reality of this phenomenon. As to life being brought from the cosmic space, we meet the necessity to test the possibility of it. H. Becquerel made recently very thorough experiments at the resistibility of the microorganisms to low temperature in the cosmic space and at their illumination with continuous ultraviolet radiation. He made a conclusion that low temperature does not serve an obstacle excluding the penetration of the latent life forms to Earth; but the ultraviolet radiation is pernicious to life. Thus, according to Becquerel, such penetration is impossible. Still it seems to me that under the endless variety of living organisms, and taking into account their utmost adaptability, this conclusion is premature. One needs new experiments.

But essentially, the question in such form (about the penetration of separate individuals to the Earth) does not meet any phenomenon actually observed in the biosphere. The question must concern the existence of a complex symbiosis which *created the biosphere.* I shall return to it in the next essay.

149. From the said above, one may make a conclusion that biology cannot decidedly answer the question whether there is an impassable gap between the living and inert bodies of the biosphere. I mean the biology based upon the now available scientific facts and empirical generalizations: the biology with its problem area as it is now being represented. In its work concerned with the explanation of life, biology proceeds from admitting the absence of such gap. But this absence is taken by it for granted, and is not derived from exactly established facts and generalizations. An analysis shows that this question remains essentially unanswered by biology.

So far, no biologist has criticized or taken into attention the opposite scientific generalization introduced by the biogeo-

*[4] Pasteur reproduce an experiment which has been done in Elton (Germany) by Keerhopon in the 1820s and then attracted attention.

chemistry into scientific thought and concerned with a deep, energetic-material difference between the living organisms and inert bodies of the biosphere: the difference which is never broken by any natural process. It remains true so far as we do not leave the ground of facts.

Two opposite scientific inferences remain existing side by side without coming into contact with one another.

Of course, this state of things cannot last for long.

The reason of this situation seems to me a very complex one. One hundred years elapsed after the crushing of the vitalistic views which for some time dominated the research work of the biologists but nothing positive came to replace these views.

One of the main causes of this is the fact that the life phenomenon is not taken by the biologists in its full manifestation. This phenomenon (as taken on its full scale) cannot be investigated scientifically if one proceeds from a living organism alone, from the natural body which is essentially analyzed by a biologist, without any preliminary logical (and not philosophical) analysis of the concepts “life” and “living organism” (not separated from its environment); without an analysis (also in connection with the environment) of the situation of the organism in the biosphere. Usually biologist says about life while studying living organisms. His generalizing thought is usually oriented to the concept of *life* and not to the concept of a living organism.

His main logical category for scientific work is the living organism, more exactly, a set of living organisms; while for his generalizing ideas he takes *life* not strictly limited to organism. A biologist starts from a single living organism, abstracted and isolated from the biosphere, while life is a planetary phenomenon building up both the biosphere and the noosphere and manifesting itself in the masses of matter. Perhaps, these masses are negligible as compared with the mass of the biosphere, but they can be quantitatively defined in the mass of the biosphere matter and play a leading part in the biosphere with reference to their energetic effect.

Looking upon life under such aspect, a biogeochemist (who deals first of all with the biological manifestations of life, with the sets of living organisms) immediately encounters a sharp, insurmountable physical-chemical distinction between the living and the inert substance.

There is *no* life outside the living organism *in the biosphere.* At a planetary scale, life is the totality of living organisms in the biosphere, with all their changes in the course of geological time.

This thesis is factually admitted by a biologist but is absent (or rather concealed) in his theoretical premises.

But it is only one (although the basic one) cause of the difference in the inferences of two trends in the biological thought: the centuries-old trend and the new, biogeochemical trend that studies life at a planetary scale, under atomic aspect.

The second basic (at any rate, really essential) cause seems to be the fact that all biological principles, both vitalistic and materialistic, did not result from scientific data but were created by the philosophic and religious conceptions. These conceptions as such are an alien body in that mass of facts, with which any biologist deals in his everyday scientific work.

150. Hardly have we here a possibility to dwell on the critique and discussion of the attempts at the materialistic or vitalistic conceptions of life.

It will be better to leave them alone. A philosophical approach to them will not advance us even to a slightest degree. All what might be said is already mostly said. And to give a picture of the real history of their penetration into science would require a deep penetration into the history of philosophical searches which are the cause of this penetration. An attempt at building up such picture would divert us far from the main purpose of the book, and at the same time would give nothing new that which might justify the spent labor.

First of all, we would have to do a great preliminary work with primary sources. For an inevitable preparation for such research is but slightly touched upon and is not done in a necessary measure. We cannot even give a right general outline of the external course of their penetration into the scientific thought. The adherents of the diverse trends give various schemes which cannot be made out (as to their correctness) without a new hard work with the initial texts.

We may limit ourselves by the following short conclusion sufficient for our purpose. For it is clear and hardly doubtful that both materialistic and vitalistic conceptions of life have entered biology in a ready form, while they have grown in another ideas area, alien to biology.

The separate biological theses tied up with these conceptions rather illustrate them than prove them or result from them. And to that, so far as I can judge, they are mainly tied up with the construction of a separate organism and thus transcend the limits of biogeochemistry which deals with the totality of organisms, i.e. with the manifestation of life as a whole in the biosphere and in the noosphere, and with the expression (partly created by life) of the structure of the biosphere and the noosphere in the aggregates of the organisms.

Thus, in the end, the centennial philosophical search of the philosophers and biologists concerning the difference between the living and the inert give us no scientifically important indications as to admitting or denying the existence of this difference.

This search is *deeply rooted in the past*, in the centennial culture of the West: both in the theological philosophical thought and in the everyday mirroring of this thought in the science of the past centuries, mainly in the science of man. The results of this search run through the work of the historians, physicians, and sociologists.

This historical past, philosophic and religious, ought to be taken into account and understood by a naturalist when he approaches these concepts.

A scientific naturalist must take it into consideration in his research. He ought not to look upon this past indifferently, as he now often does. For he may not, without a damage for his work, accept ready philosophic concepts merely because they do not constrain his creative thought or seem to him to result from the observed scientific reality.

Taking them into consideration, he inevitably inserts some conclusions in his research, which he is not conscious of and which cannot be foreseen by him without a profound criticism beyond his own strength.

A correct way for a naturalist would be to leave alone these philosophical concepts in his work, not to reckon with them.

This only will lend his scientific work more distinctness and clarity.

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THE BIOSPHERE AND THE NOOSPHERE *

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The following article is composed of an introductory abstract of a paper completed in 1938 **, and recently published in translation in the Transactions of the Connecticut Academy of Sciences (vol. 35, pp. 483-517), under the editorship of Professor G. E. Hutchinson, and a new essay, written in 1943 and translated from the Russian manuscript by Dr. George Vernadsky of Yale University. The two contributions together present the general intellectual outlook of one of the most remarkable scientific leaders of the present century.

The translation of the quotation under the frontispiece (from a letter to Professor A. Petrunkevitch) is as follows: I look forward with great optimism. I think that we undergo not only an historical, but a planetary change as well. We live in a transition to the noosphere. Cordial greetings, W. Vernadsky — *Editor.*

THE NOOSPHERE [1]

We are approaching the climax in the Second World War. In Europe war was resumed in 1939 after an intermission of twenty-one years; it has lasted five years in Western Europe, and is in its third year in our parts, in Eastern Europe. As for the Far East, the war was resumed there much earlier, in 1931, and is already in its twelfth year. A war of such power, duration and strength is a phenomenon unparalleled in the history of mankind and of the biosphere at large. Moreover, it was preceded by the First World War which, although of lesser power, has a causal connection with the present war.

In our country that First World War resulted in a new, historically unprecedented, form of statehood, not only in the realm of

* The paper is presented in fragments.

** Problems of biogeochemistry: 2. The fundamental matter-energy difference between the living and the inert natural bodies of the biosphere.

economics, but likewise in that of the aspirations of nationalities. From the point of view of the naturalist (and, I think, likewise from that of the historian) an historical phenomenon of such power may and should be examined as a part of a single great terrestrial *geological* process, and not merely as a *historical* process.

In my own scientific work the First World War was reflected in a most decisive way. It radically changed my *geological conception of the world.* It is in the atmosphere of that war that I have approached a conception of nature, at that time forgotten and thus new for myself and for others, a geochemical and biogeochemical conception embracing both inert and living nature from the same point of view [2].1 spent the years of the First World War in my uninterrupted scientific creative work, which I have so far continued steadily in the same direction.

Twenty-eight years ago, in 1915, a "Commission for the Study of the Productive Forces" of our country, the so-called KEPS, was formed at the Academy of Sciences. That commission, of which I was elected president, played a noticeable role in the critical period of the First World War. Entirely unexpectedly, in the midst of the war, it became clear to the Academy of Sciences that in Tsarist Russia there were no precise data concerning the now so-called strategjc raw materials, and we had to collect and digest dispersed data rapidly to make up for the lacunae in our knowledge[3]. Unfortunately by the time of the beginning of the Second World War, only the most bureaucratic part of that commission, the so-called Council of the Productive Forces, was preserved, and it became necessary to restore its other parts in a hurry.

By approaching the study of geological phenomena from a geochemical and biogeochemical point of view, we may comprehend the whole of the circumambient nature in the same atomic aspect. Unconsciously such an approach coincides for me with what characterizes the science of the twentieth century and distinguishes it from that of past centuries. *The twentieth century is the century of scientific atomism.*

At that time, in 1917-1918, 1 happened to be, entirely by chance, in the Ukraine [4], and was unable to return to Petrograd until 1921. During all those years, wherever I resided, my thoughts were directed toward the geochemical and biogeochemical manifestations in the circumambient nature, the biosphere. While observing them, I simultaneously directed both my reading and my reflection toward this subject in an intensive and systematic way. I expounded the conclusions arrived at gradually, as they were formed, through lectures and reports delivered in whatever city I happened to stay, in Ialta, Poltava, Kiev, Simferopol, Novorossiisk, Rostov, and so on. Besides, in almost every city I stayed, I used to read everything available in regard to the problem in its broadest sense. I left aside as much as I could all philosophical aspirations and tried to rest only on firmly established scientific and empiric facts and generalizations, occasionally allowing myself to resort to working scientific hypotheses. Instead of the concept of "life," I introduced that of "living matter," which now seems to be firmly established in science. "Living matter" is the totality of living organisms. It is but a scientific empirical generalization of empirically indisputable facts known to all, observable easily and with precision. The concept of "life" always steps outside the boundaries of the concept of "living matter"; it enters the realm of philosophy, folklore, religion, and the arts. All that is left outside the notion of "living matter."

In the course of geological time living matter morphologically changes according to the laws of nature. The history of living matter expresses itself as a slow modification of the forms of living organisms which genetically are uninterruptedly connected among themselves from generation to generation. This idea had been rising in scientific research through the ages, until, in 1859, it received a solid foundation in the great achievements of Charles Darwin (1809-1882) and Wallace (1822- 1913). It was cast in the doctrine of the evolution of species of plants and animals, including man. The evolutionary process is a characteristic only of living matter. There are no manifestations of it in the inert matter of our planet. In the cryptozoic era the same minerals and rocks were being formed which are being formed now [5]. The only exceptions are the bio-inert natural bodies connected in one way or another with living matter [6].

The change in the morphological structure of living matter observed in the process of evolution unavoidably leads to a change in its chemical composition [1].

While the quantity of living matter is negligible in relation to the inert and bio-inert mass of the biosphere, the biogenic rocks constitute a large part of its mass, and go far beyond the boundaries of the biosphere. Subject to the phenomena of metamorphism, they are converted, losing all traces of life, into the granitic envelope, and are no longer part of the biosphere. The granitic envelop of the earth is the area of former biospheres [8]. In Lamarck's book, "Hydrogflologie" (1802), containing many remarkable ideas, living matter, as I understand it, was revealed as the creator of the main rocks of our planet. Lamarck never accepted Lavoisier's (1743-1794) discovery. But that other great chemist, J. B. Dumas (1800-1884), Lamarck's younger contemporary, who did accept Lavoisier's discovery, and who intensively studied the chemistry of living matter, likewise adhered for a long time to the notion of the quantitative importance of living matter in the structure of the rocks of the biosphere.

The younger contemporaries of Darwin, J. D. Dana (1813- 1895) and J. Le Conte (1823-1901), both great American geologists (and Dana a mineralogist and biologist as well) expounded, even prior to 1859, the empirical generalization that *the evolution of living matter is proceeding, in a definite direction.* This phenomenon was called by Dana "cephalization," and by Le Conte the "psychozoic era." Dana, like Darwin, adopted this idea at the time of his journey around the world, which he started in 1838, two years after Darwin's return to London, and which lasted until 1842 [9].

Empiric notions of a definite direction of the evolutionary process, without, however, any attempt theoretically to ground them, go deeper into the eighteenth century. Buffon (1707-1788) spoke of the "realm of man," because of the geological importance of man. The idea of evolution was alien to him. It was likewise alien to Agassiz (1807-1873), who introduced the idea of the glaciafperiod into science. Agassiz lived in a period of an impetuous blossoming of geology. He admitted that geologically the realm of man had come, but, because of his theological, tenets, opposed the theory of evolution. Le Conte points out that Dana; formerly having a point of view close to that of Agassiz, in the last years of his life accepted the idea of evolution in its then usual Darwinian interpretation [10]. The difference between Le Conte's "psychozoic era" and Dana's "cephalization" thus disappeared. It is to be regretted that, especially in our country, this important empirical generalization still-remains outside the horizon of our biologists.

The soundness of Dana's principle, which happens to be outside the horizon of our palaeontologists, may easily be verified by anyone willing to do so on the basis of any modem treatise on palaeontology. The principle not only embraces the whole animal kingdom, but likewise reveals itself clearly in individual types of animals. Dana pointed out that in the course of geological time, at least two billion years and probably much more, there occurs an irregular process of growth and perfection of the central nervous system, beginning with the crustacea (whose study Dana used to establish his principle), the molluscs (cephalopoda), and ending with man. It is this phenomenon that he called cephalization. The brain, which has once achieved a certain level in the process of evolution, is not subject to retrogression, but only can progress further.

Proceeding from the notion of the geological njie of man, the geologist A. P. Pavlov (1854-1929) in the last years of his life used to speak of the *anthropogenic era* in which we now live. While he did not take into the account the possibility of the destruction of spiritual and material values we now witness in the barbaric invasion of the Germans and their allies, slightly more than ten years after his death, he rightly emphasized that man, under our very eyes, is becoming a mighty and ever-growing geological force. This geological force was formed quite imperceptibly over a long period of time. A change in man's position on our planet (his material position first of all) coincided with it. In the twentieth century, man, for the first time in the history of the earth, knew and embraced the whole biosphere, completed the geographic map of the planet Earth, and colonized its whole surface. *Mankind became a single totality in the life of the earth.* There is no spot on earth where man can not live if he so desires. Our people's sojourn on the floating ice of the North Pole in 1937-1938 has proved this clearly. At the same time, owing to the migthy techniques and successes of scientific thought, radio and television, man is able to speak instantly to anyone he wishes at any point on our planet. Transportation by air has reached a speed of several hundred kilometers per hour, and has not reached its maximum. All this is the result of "cephalization," the growth of man's brain and the work directed by his brain.

The economist, L. Brentano, illuminated the planetary sig nificance of this phenomenon with the following striking computation: if a square meter was assigned to each man, and if all men were put close to one another, they would not occupy the area of even the small Lake of Constance between the borders of Bavaria and Switzerland. The remainder of the earth's surface would remain empty of man. Thus the whole of mankind put together represents an insignificant mass of the planet's matter. Its strength is derived not from its matter, but from its brain. If man understands this, and does not use his brain and his work for self-destruction, an immense future is open before him in the geological history of the biosphere.

The geological evolutionary process shows the biological unity and equality of all men, *Homo sapiens* and his ancestors, *Sinanthropus* and others; their progeny in the mixed white, red, yellow, and black races evolves ceaselessly in innumerable generations [1] *. This is a *law of nature.* In a historical contest, as for instance in a war of such magnitude as the present one, he finally wins who follows that law. One cannot oppose with impunity the principle of the unity of all men as a law of nature. I use here the phrase *law of nature* as this term is used more and more in the physical and chemical sciences, in the sense of an empirical generalization established with precision.

The historical process is being radically changed under our very eyes. For the first time in the history of mankind the interests of the masses on the one hand, and the free thought of individuals on the other, determine the course of life of mankind and provide standards for men's ideas of justice. Mankind taken as a whole is becoming a mighty geological force. There arises the problem of the *reconstruction of the biosphere in the interests of freely thinking humanity as a single totality.* This new state of the biosphere, which we approach without our noticing it, is the nousphere.

In my lecture at the Sorbonne in Paris in 1922-23,1 accepted *biogeochemical phenomena* as the basis of the biosphere. The contents of part of these lectures were published in my book, "Studies in Geochemistry," which appeared first in French, in 1924, and then in a Russian translation, in 1927 [12]. The French mathematician Le Roy, a Bergsonian philosopher, accepted the biogeochemical foundation of the biosphere as a starting point, and in his lectures at the CollHge de France in Paris, introduced in 1927 the concept of the nousphere as the stage through which the biosphere is now passing geologically [13]. He emphasized that he arrived at such a notion in collaboration with his friend Teilhard de Chardin, a great geologist and palaeontologist, now working in China.

The noosphere is a new geological phenomenon on our planet. In it for the first time man becomes a *large-scale geological force.* He can and must rebuild the province of his life by his work and thought, rebuild it radically in comparison with the past. Wider and wider creative possibilities open before him. It may be that the generation of our grandchildren will approach their blossoming.

Here a new riddle has arisen before us. *Thought is not a form of energy.* How then can it change material processes? That question has not as yet been solved. As far as I know, it was first posed by an American scientist bom in Lvov, the mathematician and biophysicist Alfred Lotka [14]. But he was unable to solve it. As Goethe (1740-1832), not only a great poet but a great scientist as well, once rightly remarked, in science we only can know *how* something occurred, but we cannot know *why* it occurred.

As for the coming of the noqsphere, we see around us at every step the empirical results of that “incomprehensible” process. That mineralogical rarity, native iron, is now being produced by the billions of tons. Native aluminum, which never before existed on our planet, is now produced in any quantity. The same is true with regard to the countless number of artificial chemical combinations (biogenic “cultural” minerals) newly created on our planet. The number of such artificial minerals is constantly increasing. All of the *strategic raw materials* belong here. Chemically, the face of our planet, the biosphere, is being sharply changed by man, consciously, and even more so, unconsciously. The aerial envelope of the land as well as all its natural waters are changed both physically and chemically by man. In the twentieth century, as a result of the growth of human civilization, the seas and the parts of the oceans closest to shore become changed more and more markedly. Man now must take more and more measures to preserve for future generations the wealth of the seas which so far have belonged to nobody. Besides this, new species and races of animals and plants are being created by man. Faiiy tale dreams appear possible in the future: man is striving to emerge beyond the boundaries of his planet into cosmic space. And he probably will do so.
At present we cannot afford not to realize that, in the great histor

ical tragedy through which we live, we have elementally chosen the right path leading into the noosphere. I say elementally, as the whole history of mankind is proceeding in this direction. The historians and political leaders only begin to approach a comprehension of the phenomena of nature from this point of view. The approach of Winston Churchill (1932) to the problem, from the angle of a historian and political leader, is very interesting[15].

The nousphere is the last of many stages in the evolution of the . biosphere in geological history. The course of this evolution only begins to become clear to us through a study of some of the aspects of the biosphere's geological past. Let me cite a few examples. Five hundred million years ago, in the Cambrian geological era, skeletal formations of animals, rich in calcium, appeared for the first time in the biosphere; those of plants appeared over two billion years ago. That calcium function of living matter, now powerfully developed, was one of the most important evolutionary factors in the geological change of the biosphere [16]. A no less important change in the biosphere occurred from seventy to one hundred and ten million years ago, at the time of the Cretaceous system, and especially during the Tertiaiy. It was in this epoch that our green forests, which we cherish so much, were formed for the first time. This is another great evolutionary stadium, analogous to the nousphere. It was probably in these forests that man appeared, around fifteen or twenty million years ago.

Now we live in the period of a new geological evolutionary change in the biosphere. We are entering the nousphere. This new elemental geological process is taking place at a stormy time, in the epoch of a destructive world war. But the important fact is that our democratic ideals are in tune with the elemental geological processes, with the laws of nature, and with the nousphere. Therefore we may face the future with confidence. It is in our hands. We will not let it go.

Borovoe, July 22/Moscow, December 15, 1943.

NOTES AND REFERENCES

1. The word “nousphere” is composed from the Greek terms *noos,* mind, and *sphere,* the last used in the sense of an envelope of the earth. I treat the problem of the nousphere in more detail in the third part of my book, now being prepared for publication, on *The Chemical Structure of the Biosphere of the Earth as a Planet, and its Surroundings.*
2. It should be noted that in this connection. Icame upon the forgotten thoughts

of that original Bavarian chemist, C. Schoenbein (1799 -1868) and of his friend, the English physicist of genius, M. Faraday (1791 -1867). As early as the beginning of the eighteen-forties, Schoenbein attempted to prove that.a new division should be created in geology-geochemistry, as he called it. See W. Vernadsky, *Ocherki geokhimii* (Studies in Geochemistry), 4th edition, Moscow-Leningrad, 1934, pp. 14, 290

3. On the significance of KEPS see A. E. Fersman. *Voina i strategicheskoe syrie* (The War and Strategic Raw Materials). Krasnoufimsk, 1941, p. 48.
4. *See my article. Out of my Recollections: The First Year of the Ukrainian*

Academy of Sciences, to appear in the Jubilee volume of the Ukrainian

Academy of Sciences, in commemoration of its twenty-fifth anniversary.

5. In accordance with modem American geologists as, for example, Charles Schuchert (Schuchert and Dunbar, *A Textbook of Geology,* 11, New York, 1941, p. 88ff.), I call the Cryptozoic era that period which formerly had been called die Azoic, or the Archaeozoic, era. In the Cryptozoic era the morphological preservation of the remnants of organisms dwindles almost to nothing, but the existence of life is revealed in the organogenic rocks, the origins of which arouse no doubts.
6. On the bio-inert bodies see W. I. Vernadsky, *Problems of Biogeochemistry,* II, Trans. Conn. Acad. Arts Sci., vol. 35 (1944), pp. 493-494. Such are, for example, the soil, the ocean, the overwhelming majority of terrestrial waters, the troposphere, and so on.
7. This problem urgently needs experimental verification. It has been set forth by the Laboratory of Geochemical Problems in collaboration with the Palaeontological Institute of the Academy of Sciences, in the plan of our work for 1944.
8. See my basic work referred to in Note 7.
9. One should not fail to note here that the expedition during which Dana came to his conclusions concerning cephalization, the coral islands, and so on, actually and historically was closely connected with the exploration of the Pacific by Russian navigators, especially Rrusenstem (1770 -1846).

See D. Gilman, *The Life of J. D. Dana*, New York, 1899. The chapter on the oceanic expedition in this book was written by Le Conte. Le Conte’s book. *Evolution* (1888), has not been accessible to me. His autobiography was published in 1903: W. Armes, Editor, *The Autobiography of Joseph Le Conte.* For his biography and bibliography see H. Fairchild in Bull. Geol. Soc. Amer. 26 (1915), p. 53. It was the report on the Russian travels, published in German in 1827, which spurred the American lawyer, John Reynolds, to insist on the organization of a similar American scientific oceanic expedition. Owing to

Reynolds' persistence, the expedition eventually materialized, but not until eleven years afterwards, in 1838. This was the Wilkes expedition, which finally proved the existence of the Antarctic.

On Reynolds see the Index in ***Centenary Celebration: Wilkes Exploring Expedition of the U.S. Navy, 1838 - 1842,*** Proc. Amer. Philos. Soc., 82, No. 5 (1940). It is to be regretted that our expeditions in the Pacific, so active in the first half of the nineteenth century, were later discontinued for a long time (almost until the Revolution), following the death of both Emperor Alexander I (1777-1825} and Count N. P. Rumiantsov (1754-1826) — that remarkable leader of Russian culture who equipped the "Riurik" expedition (1815-1818) out of his private funds.

In the Soviet period K. M. Deriugin's (1878 -1936) expedition should be mentioned, its precious and scientifically important materials have been so far only partly studied and remain unpublished. Such an attitude toward scentific work is inadmissible, The Zoological Museum of the Academy of Sciences must fulfill this scientific and civic duty.

10. D. Gilman, o.c., p. 255.

11. I and my contemporaries have imperceptibly lived through a drastic change in the comprehension of the circumambient world. In the time of my youth it seemed both to me and to others that man had lived through a historical time only, within the span of a few thousand years, at best a few tens of thousand of years. Now we know that man has been consciously living through tens of millions of years. He consciously lived through the glacial period in both Eurasia and North America, through the formation of Eastern Himalaya, and so on. The division of historical and geological time is leveled out for us.

12. The last revised edition of my ***Ocherki Geokhimii*** (Problems of Geochemistry) appeared in 1934. In 1926 the Russian edition of ***Biosfera*** (The Biosphere) came out, and in 1929 its French edition. My ***Biogeokhimicheskie Ocherki*** (Biogeochemical Studies) was published in 1940. The publication of ***Problemy biogeokhimii*** (Problems of Biogeochemistry) was begun in 1940. (A condensed English translation of Part 11 appeared, under the editorship of G. E. Hutchinson, in Trans. Conn. Acad. Arts Sci., vol. 35 in 1944.) Part III is in press. ***Ocherki geokhimii*** was translated into German and Japanese.

13. Le Roy's lectures were at once published in French: ***L'exigence idiktliste et le fait d'involution,*** Paris, 1927, p. 196.

14. A. Lotka, ***Elements of Physical Biology,*** Baltimore, 1925, p. 405 f.

15. W.S. Churchill, ***Amid These Storms: Thoughts and Adventures.*** New York, 1932, p. 274 f. I plan to return to this problem elsewhere.

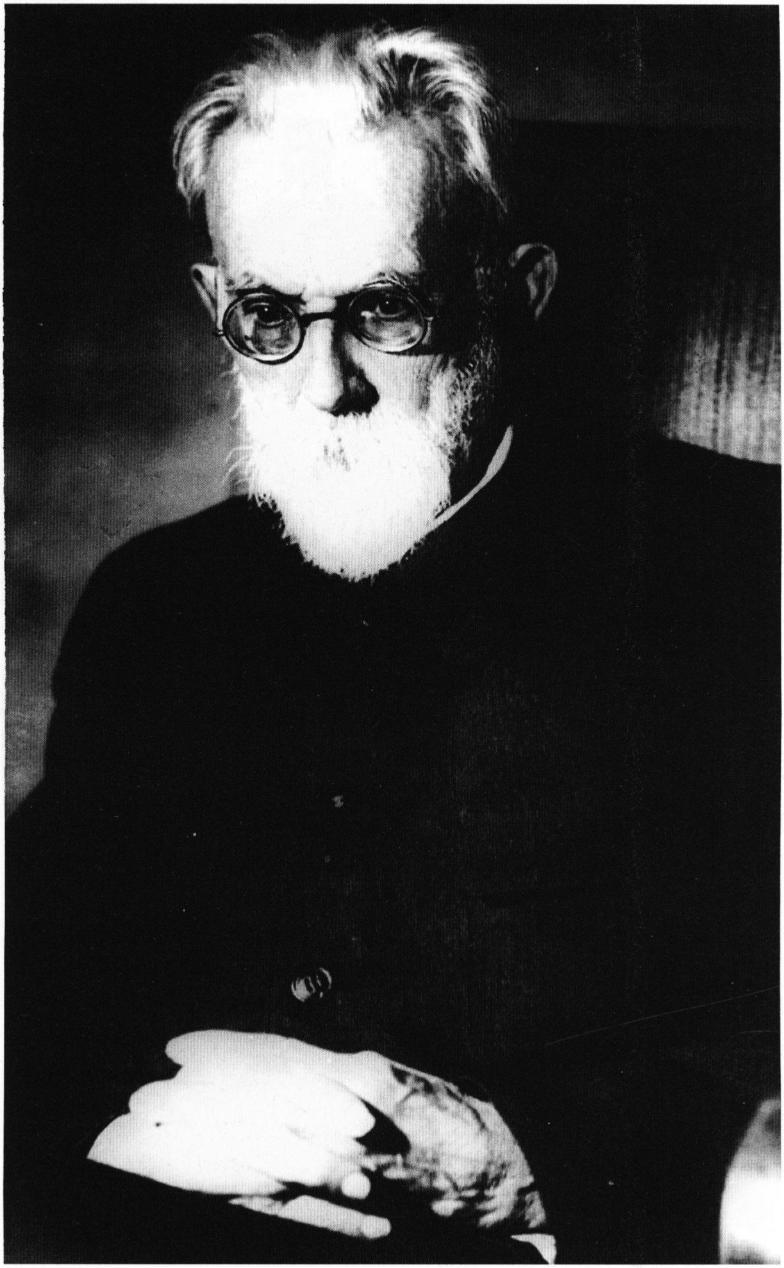
16. I deal with the problem of the biogeochemical functions of organisms in the second part of my book. ***The Chemical Structure of the Biosphere*** (see Note 7).

V.I. Vernadsky - Professor of Moscow University, 1905.

From left to right: sitting - N.D.Zelinsky, I.A.Kablukov, N.M.Kizhnev, A.N.Severtsov; standing - N.N.Luzin, M.N.Rozanov, V.I. Vernadsky, 1934.

V.I.Vernadsky and A.E.Fersman, 1940.

V.I.Vernadsky in his working study, 1940.



The lastmost photograph of V.I.Vernadsky, Moscow, 1944.

THE MAIN DATES OF LIFE AND WORK OF ACADEMICIAN V.I.VERNADSKY

Vladimir Ivanovich Vernadsky was bom in Petersburg, March 12, 1863.

1873-1876 Studied in the First classical gymnasium (Kharkov).

1876-1881 Studied in the First classical gymnasium (Petersburg).

1881-1885 Student of the physical-mathematical faculty (natural-scien tific section) of the Petersburg University.

1882 Participated in a general student meeting. Arrested.

1882, 1884. Participated in the Nizhny Novgorod soil expedition (head ed by V.V.Dokuchaev).

1885 Graduated from the physico-mathematical faculty of the Petersburg University; left at the University to prepare for professorship.

1885-1890 Keeper of the Mineralogical cabinet of the Petersburg University.

1886 Elected a full member of the Petersburg Society of naturalists.

1887 Elected a member of the Free economical society. Sent by the Society to study the phosphorities of the Roslavl’ region of the Smolensk province.

1888-1890 Sent by the Petersburg University to Italy, Germany and France for further education.

1889 Elected a coresponding member of the British association of sciences.

Elected a member of the French mineralogical society. Participated in the International exhibition in Paris (presenting the soil collection of V. V. Dokuchaev).

1890 Settled in Moscow. Becomes a private-docent for teaching mineralogy and crystallography and temporary keeper of the Mineralogical cabinet of the Moscow University.

Elected a member of the Moscow Society of naturalists.

1890-1911 Professor of mineralogy and crystallography of the Moscow University.

1891 ***Maintained (in the Petersburg University) the magister thesis On the sillimanite group and on the role of the alumina in the silicates.***

Elected a member of the Society of the naturalists, anthropologists, and etnographers at the Moscow University. Elected a member of the Moscow Society of agriculture.

1892 Becomes the keeper of the Mineralogical cabinet of the Moscow University.

1893 Elected a member of the Mineralogical society (Petersburg). Elected a member of the Society for empirical knowledge at the University of Kharkov.

Studied the soils of the Poltava province.

1884 Dispatched to Europe for research and visiting mineralogical museums of Austria-Hungary, Germany, Switzerland, France. For the first time in Russia, introduced regular mineralogical expedition with students into curricula.

1895 - 1897 Expeditions on the Urals.

1896 Sent on a research mission to Europe (Germany, Switzerland, France).

1897 Defended (at the University of Petersburg) his thesis for a Doctoral degree: ***The phenomena of the sliding of the crystalline substance.***

Participated in the second session of the International Geological Congress (Petersburg).

1897- 1906 Professor of mineralogy at the Momen’s team courses (Moscow).

1898 A scientific voyage to Europe (Italy, Austria-Hungary, Germany, France).

1898- 1902 The extraordinary professor of the Moscow University.

1899 Geological-mineralogical expeditions in Crimea, Kerch and Taman Peninsulas, and Caucasus.

1900 A voyage over the European countries: Germany, Denmark, Netherlands, France. Participated in the work of the 8th session of the International Geological Congress (Paris).

1901 Geological expeditions in the Tambov and Poltava provinces. Organized (at the Mineralogical cabinet) a circle which became a formal nucleus for a mineralogical school.

1902 Elected a member of the Psychological Society (Moscow).

A geological expedition to the Caucasus.

Voyaged over Europe. Worked in the libraries of Berlin,

Tom, Copenhagen; studied the collections in the mineralogical museums of Dresden, Freiberg, and Prague.

1902-1903 Lectured at the Moscow University on the history of natural

sciences.

1902-1911 An ordinary professor in the Moscow University.

1903 Elected a member of the Lvov Shevchenko scientific society. A voyage over Europe (Germany, Austria-Hungary). Participated in the work of the 9th session of the International Geological Congress (Vienna) and in the expedition over the mineral deposits of Bosnia.

1904 Geological expeditions over the Poltava and Kiev provinces. Participated in the work of the First general congress of the zemstvos in Petersburg.

1905 Elected an assistant rector of the Moscow University Elected a member of the All-Russian league of enlightenment. Became a member of the Constitutional-democratic party.

1906 Elected a full adjunct member of the Petersburg Academy of sciences by the physical-mathematical department (mineralogy).

Elected a member of the State council from the Academy of sciences and universities. Left the State council as a sign of protest against the declining of a draft law of the Duma and against the dismissal of the State Duma.

1906-1914 Manager of the Mineralogical department of the Geological

museum of the Academy of sciences.

1907 Organized the first expedition after the radioactive minerals on the territory of Russia.

Sent for a mission to the Scandinavian countries and Germany.

1908 Elected to the Academy of sciences as an extraordinary academician in mineralogy.

Elected to the State council for the second time.

Sent for a mission to France and Great Britain.

Participated in the work of the Congress of the British Assosiation of sciences in Dublin.

Elected a member of the Committee for Slavish interactions. Elected a member of the Society of the Slavish culture.

1909 Elected a member of the Society for the unification of the Russia’s peoples.

Elected a member of the Ledentsov society for the advancement of the empirical sciences.

Participated in the 12th congress of Russian naturalists and physicians in Moscow. Read a program report *Paragenesis of the chemical elements in the earth crust.*

Made a long trip over the countries of the Western Europe.

A geological expedition to the Volyn' province.

1910 Wrote a report *On the necessity for studying the radioactive minerals of the Russian empire.* After V. I. Vernadsky's initiative, the Commission on radium became created in the Academy of sciences.

Read a report *Topical targets in the area of radium research* at the general meeting of the Academy of sciences, December 29.

1911 Resigned from the Moscow University in token of protest against the reaction policy of the Czar government.

Moved to Petersburg.

Expelled from the State council.

Dispatched to France, Germany, Austria, and Switzerland for research.

Read the report *Radioactive area in the Earth crust* at the Second congress of practical geologists (Petersburg).

Read the report *On the exchange of gazes in the Earth crust* at the Second Mendeleev congress (Petersburg).

Organized and headed the expeditions of the Academy of sciences searching the radium minerals in Transcaucasia, Middle Asia, and the Urals.

Elected a member of the Russian geographical society. Elected a honorary member of the Tiflis society of naturalists.

Elected an honorary member of the Moscow society of naturalists.

Elected a member of the Society of the workers of periodical press and literature.

1911-1915 Manager of the Mineralogical museum of the Academy of sciences (Petersburg).

1912 Elected an ordinary academician of the Academy of sciences. Organized and headed the permanently acting radium expedition of the Academy of sciences.

Elected a member of the Society for studying Siberia and improving the life of its population.

Elected a member of the Gertsen Literary-artistic circle as well as of its inspection commission.

Elected a member of the Society for the aid to the literators and scientists.

1913 Participated in the 13th session of the International Geological Congress in Toronto; made excursions in Canada and USA. Elected a honorary member of the Moscow society of naturalists, anthropologists, and etnographers.

Elected a honorary member of the Urals society of naturalists. Appointed the director of the Geological and Mineralogical museum of the Academy of sciences (Petersburg).

1914 Elected an honorary member of the mineralogical society (Petersburg).

1915 Elected a member of the State council from the Academy of sciences and universities.

Dispatched to the Vyatka, Perm, Tavria, and Ekaterinburg provinces for mineralogical research.

1915-1918, Chairman of the council of the Commission on studying

1921-1930 the natural productive forces ofRussia. (The Commission had been formed after V. I. Vernadsky's initiative at the Academy of sciences).

1917 Elected the chairman of the Agricultural learned committee of the Ministry of agriculture.

Appointed the chairman of the Commission on learned organizations and scientific enterprises of the Ministry of people's education.

Elected the assistant minister of people's education.

Sent to Poltava for a mission consisting in the continuation of work on biogeochemistry and living substance.

1918 Moved to Kiev. Began to read the course of geochemistry in the University of Kiev.

Elected the chairman of the Commission on studying natural productive forces of the Ukraine.

Dropped out of the Constitutional-democratic party.

Elected a member of the Russian society for the dissemination of the natural-scientific education.

1918- 1919 A foundating member and the first president of the Ukrainian Academy of sciences.

1919 Moved to Simferopol.

1919- 1921 Professor and (since 1920) rector of the Tauria University in Simferopol. Organized a laboratory "Role of the living organisms in the mineralogenesis" at the University.

1921 Moved to Petrograd.

Head of the Commission on the history of science, philosophy and technology, which had been formed, after V. I. Vernadsky's initiative, in the Russian academy of sciences.

Worked in the area of marine chemistry at the Murmansk biological station at the Aleksandrovskaya harbour.

Elected the professor of mineralogy of the University of Paris (Sorbonne).

1921- 1939 Manager of the Meteorite section of the Mineralogical museum in Leningrad.

1922- 1926 Scientific mission to France for reading a course in geochemistry at Sorbonne and for research at the Mineralogical laboratory of the Museum of natural history and in the P. Curie Radium institute.

1922-1929 Director of the Radium institute organized after his initiative in Petrograd.

1925 Worked on biogeochemistry in Paris and Prague.

1926 Returned to Leningrad.

Elected a foreign member of the Czech Academy of sciences and arts, and a corresponding member of the Naturalists' club in Prague.

Elected a foreign member of the Yugoslavian Academy of sciences and arts.

Elected a member of the Geological society of France. Elected a member of the German chemical society.

Elected a member of the American mineralogical society. Elected a member of the German mineralogical society.

Restored the work of the Commission on the history of knowledge; elected its chairman.

Elected a member of the Society for the studies in the history, literature and language of the Ukraine.

Elected a member of the Historical, archaeological and ethnographical society of Tauria.

1927, 1928 Dispatched to France, Netherlands, Czechoslovakia,

1929 Norway, Germany, and Sweden for lecturing and research.

1928 Elected a corresponding member of the Paris Academy of sciences (section of mineralogy).

1928-1945 Managed the Biogeochemical laboratory of the Academy of sciences of the USSR.

1929 A member of the Commission on the elaboration of the new structure and new statute of the Academy of sciences of the USSR.

1930 Elected a corresponding member of the Mineralogical and geological society of Czechoslovakia.

Elected president of the Leningrad society of naturalists. Participated in the work of the Second international congress of soil science (Leningrad).

1931 Read the report *Problem of time in contemporary science* at the general meeting of the USSR Academy of sciences (December 26).

1932 Sent for scientific mission to Germany, France and Czechoslovakia.

Participated in the work of the First international congress on radioactivity (Germany).

Guided the work of the First All-Union conference on radioactivity problems (Leningrad).

1933 Was at the head of the Meteorites commission formed after his initiative in the USSR Academy of sciences.

1934 Elected the chairman of the Commission on heavy water studies organized by him in the USSR Academy of sciences. Participated in the work of the All-Union conference on the study of the stratosphere. Read the report *Biosphere and stratosphere.*

1935 Moved to Moscow.

Elected the vice-president of the Moscow society of naturalists.

Headed the studies on the aetiology and prophylaxy of endemic diseases.

1935, 1936 Scientific missions to Czechoslovakia, France, Germany, England.

1936 Elected an honorary member of the Society of biological chemistry of India.

Participated in the Second Conference on experimental mineralogy and petrography (Moscow). Read the report *On the importance of radiogeology for modern geology.*

Elected the vice-president of the International commission on geological time organized after his initiative.

1938 Elected a foreign corresponding member of the Belgian geological society.

1939 Elected a member of three sections of the USSR Academy of sciences (geological-geographical, chemical and physico- mathematical sciences).

1939-1945 The chairman of the Committee on meteorites of the USSR Academy of sciences, the Commission on the isotopes of the USSR Academy of sciences, the Commission on the mineral waters of the USSR Academy of sciences, the Commission on the studies of permafrost of the USSR Academy of sciences, the Commission of the study, use and preservation of the underground waters, the Commission on the determination of the geological age of the rocks of the USSR Academy of sciences, of the Uranium commission at the Presidium of the USSR Academy of sciences.

1940 Participated in the work of scientific conferences (1) on comparative physiology and (2) on the pegmatite problem (both in Kiev).

1941-1943 Evacuated with a group of scientists to Borovoe (Kazakhstan), where continued research into various scientific problems.

1943 Returned to Moscow from evacuation.

Awarded the State Prize of the USSR for eminent works of many years in science and technology.

Awarded an order of Labor Red Banner for the outstanding merits in the development of geochemistry and genetic mineralogy.

1944 Elected an honorary member of the Mendeleev All-Union chemical society.

Confirmed in his tenure of a member of the Commission of the USSR Academy of sciences on the history of biological sciences in Russia.

1945 Died January 6, 1945 in Moscow. Buried at the Novodevichye cemetery.

Nongovernmental Ecological V. I. Vernadsky Foundation

V.I.Vernadsky Foundation was founded in August, 1995, by the initiative of RAO "Gazprom", RAO "EES Rossii" Energy and Electrification Company, "Lukoil" Oil Company, the Russian Oil Exporters Union, the Savings Bank of Russia, some others ministries and departments.

The President of the Nongovernmental Ecological V.I.Vernadsky Foundation is R.I.Vyakhirev, the Chairman of the Board of RAO "Gazprom". The Chairman of the Foundation's Expert Council is the vice-president of Russian Academy of Sciences, academician N.P.Laverov.

In it's activities V.I.Vernadsky Foundation follows the principles set up by "The Agenda for the 21 st Century" and by the Presidential Decree "On the Concept of the Transition of Russia to Sustainable Development."

Along with this, V.I.Vernadsky Foundation is guided by the idea, that successful implementation of the program of sustainable development of Russia depends on coordination of the activities of organizations of varioys countries, which find their goal in construction of a society oriented to sustainable development.

The main goals and objectives of Foundation are the following: assistance to constant, ecologically aimed social and economic development of the Russian Federation; protection and improvement of health of Russian people; creation of conditions for their harmonic spiritual and cultural progress.

There are the next priorities of Foundation's activities:

1. Financial and economic analysis and estimation of investment projects, ecological consulting and auditing;
2. Development, financing and providing of credits for

ecological programmes and for gas- and oil-extraction projects as well as processing enterprises;

3. Ecological monitoring.

This not an occasion that the Foundation is named after V.I.Vernadsky - a prominent Russian scientist, who made an inestimable contribution to the strengthening of the idea of the supremacy of reason, scientific thinking over the evolution of the society. The promotion of creative and scientific heritage of V.I. Vernadsky is one of the core orientations of the activities of the Foundation.

With the purpose of propaganda and creative development of V.I .Vernadsky's ideas the Foundation shall carry out the following functions: arrangement of annual conferences on study and development of scientific heritage of V.I.Vernadsky; preparation and financing of publication of the complete works of V.I.Vernadsky; establishment of ties with scientific and educational institutions aimed at promoting V.I.Vernadsky's ideas; support of research in the fields of environmental protection, rational and complex use of natural resources and public health.

According to the Foundation's Charter, individual Russian programmes and international projects focused on ecology are supported by its annual grants. The V.I.Vernadsky Foundation declared the grant contest in the following areas: A - Ecology Legislation; B - Social Ecology; C - Training and Education in Ecology; D - Ecology of Humans and the Nature; E - Natural Resources Ecology; F - Ecology of Technical Systems and Technologies; G - Environmental Monitoring; H - Environmental Aspects of the Russian Fuel and Energy Industries.

Besides, with an aim to promote education and scientific work of intramural students at higher institutions in ecology, and to encourage the study and advocacy of V.I Vernadsky's scientific heritage the Nongovernmental Ecological V.I.Vernadsky Foundation have been established the Vernadsky Studentships. The Vernadsky Studentships will be assigned on a competitive basis to ecology students of higher educational institutes in Russia and universities abroad, based on their examination results.

The "Concept of the Transition of Russia to Sustainable Development" reads as follows: "The movement of humanity to steady development will lead finally to formation of the predicated by Vernadsky sphere of reason (noosphere), when spiritual values and knowledge of humanity, existing in harmony with environment, will become a standart of national and individual health".

The activity of the Nongovernmental Ecological V.I.Vernadsky Foundation is aimed at harmonization of interaction between human being and nature.

In the light of the aforementioned, the administration of V. I.Vernadsky Foundation claims its interest in the onset and development of partnership with all relevant organizations and proves its eagerness to business and mutually profitable relations.

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