The Transition From the Biosphere To the Noösphere

by Vladimir Vernadsky

Excerpts from
Scientific Thought as a Planetary Phenomenon
1938

Translated by William Jones

Vladimir Ivanovich Vernadsky
1863-1945

Introduction

by William Jones

The name of Vladimir Ivanovich Vernadsky may be familiar to many people involved in the area of science, particularly in the geological and so-called "earth" sciences, but most of these scientists, without a good working knowledge of Russian, will only have known his work, at best, through the publication of his 1926 monograph, "The Biosphere," which brought him some immediate international attention since it soon appeared (in 1929) in a French edition. This has since been translated into many languages, although first appearing in English only in 1986. Since the 1980s, the work of Vernadsky has been widely circulated and popularized by the movement led by U.S. economist and statesman Lyndon LaRouche, whose work on economics has, over the last few decades, been most significantly influenced by Vernadsky's concept of the noösphere. In their view of man and man's possibilities for development they are kindred souls.

In Russia, Vernadsky's name is as familiar as that of Pasteur or Curie or Einstein. President Vladimir Putin has decreed that the 150th anniversary of Vernasky's birth next year will be the occasion for celebration throughout the country. While much of Vernadsky's early work first appeared in French scientific journals, most of his major works, including his last, unfinished, magnum opus, "The Chemical Structure of the Biosphere and Its Surroundings," exists only in Russian. In fact, since Vernadsky, working for the first part of his life under the Tsarist regime and the last part under the Soviet regime, was in both cases considered something of a "dissident," many of his most path-breaking and creative works were not published until well after his death.

Vernadsky's life covers a long and dramatic span of Russian history. Born in 1863 in the midst of the great reforms initiated by Alexander II and living until the very eve of the end of World War II, dying in January, 1945, Vernadsky was an active participant in some of the greatest upheavals of that era. Born in St. Petersburg, he spent much of his early life and young manhood in Ukraine, the family having its roots in that region.

Studying during one of the most fertile periods in Russian science under the great chemist Dmitry Mendeleyev, and the renowned soil scientist V.I. Dokuchaev, Vernadsky was first drawn to the study of crystallography and mineralogy. Vernadsky went on expeditions with Dokuchaev to study the fertile "black earth" of Ukraine, where his attention was first attracted to the elements of living organisms that contributed to that soil's tremendous productivity. Indeed, it would be later, during his temporary exile in Ukraine after the Bolshevik Revolution that Vernadsky would first develop his own unique concept of the role of the "biosphere."

But Vernadsky, like Leonardo da Vinci, one of his great heroes in the realm of science, was also something of a universal genius. His interests spread over the entire gamut of scientific thought. And like Leonardo, his seminal work in so many areas provided the basis for further research in entirely new fields of research: genetic mineralogy, geochemistry, hydrogeochemistry and hydrogeothermy, oceanography, radiogeology, cryology or the study of permafrost, and cosmochemistry. He virtually created the field of biogeochemistry and his insistence on studying the chemistry of other planets to find the similarities—and dissimilarities—to our own, foreshadowed much of the work that would reach fruition after his death in the manned space program.

Ivan Vasilievich Vernadsky with his family. Vladimir is standing on the far right.

In all these areas Vernadsky left his imprint. And in his extensive work as a teacher and scientist he also left an extensive school of scientific thought that still makes itself felt in Russia today. In fact, one might say with justification, that Russian science is still on the "cutting

Russian Academy of Sciences

Vladimir Vernadsky with other members of the Russian Duma circa 1905.

edge" largely thanks to the "Vernadsky school," which, of course, would include not only his own students, but theirs as well, as well as the numerous individuals who have been attracted to science by the work and example of Vernadsky.

While he worked half his life in Tsarist Russia and the other half under the Soviet regime, he was an adherent of neither. His devotion was to the nation, and he was democratic in spirit, putting him somewhat at odds with both of these political systems. In his younger days, prior to the Bolshevik Revolution, he had been extremely political. His father, Ivan Vasilievich Vernadsky, was a prominent Russian economist who introduced the work of American economist Henry Charles Carey to Russian circles and helped lay the basis for the great reforms of the 1860s. Vladimir was deeply involved in the reform movement of his own time, helping to transform the illegal Union of Liberation (which he helped to establish), into the Constitutional Democratic Party (Kadets) when political parties were finally permitted in Russia after the 1905 Revolution. Vernadsky served on the Central Committee of the Kadets from 1903 until 1917 and for brief periods in the Duma as a Kadet delegate.

When the Bolsheviks took power, Vernadsky, diagnosed with tuberculosis, removed himself to his country home in Ukraine. While in Ukraine in 1919-1920 he set up the Ukrainian Academy of Sciences and established in the capital, Kiev, the National Library of Ukraine which still bears his name. When Kiev fell to the Bolsheviks, Vernadsky withdrew to Crimea, still under the control of the Whites. Here he was elected president of the Tauride University.

When Crimea fell to the Bolsheviks, Vernadsky was considering emigrating to the United States where he hoped he would be able to set up a Biogeochemical Laboratory under the Carnegie Institute. But his election to the presidency of Tauride University and a deep-rooted concern for the fate of Russian science under Bolshevik rule, kept him in Crimea where many Russian intellectuals had sought refuge. With the fall of Crimea to the Bolsheviks, Vernadsky, although known as an active member in the Kadet Party, was brought back to St. Petersburg, not as a prisoner, but in order to again take up his position at the

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Teaching geochemistry at the Higher Women's Course in St. Petersburg.

U.S. National Institutes of Health

Florentine physician and scientist Francesco Redi (1627-1697).

Mineralogical Museum which he had left three years before. Lenin's policy of broad electrification of the Soviet Union necessitated a revival of the old scientific cadre from the pre-war period. Vernadsky, who had been a teacher and a mentor for Lenin's brother, Alexander, prior to Alexander's involvement in an attempted assassination of the Tsar in 1881, was also not totally unknown to Lenin.

During the often tumultuous and difficult years following the Russian Revolution and civil war, Vernadsky would steadily work to revive and advance Russian science. Until the mid 1930s, he was permitted to travel abroad almost every year, consolidating contacts with the main figures in international science, with Marie Curie in Paris, with Otto Hahn in Germany, and with Lord Rutherford and Frederick Soddy in England.

Vernadsky almost single-handedly conducted a campaign in Russia to establish a major research center for nuclear energy. Already in 1921 he had succeeded in creating the *Radium Institute in St. Petersburg,* but the Soviet leadership was slow to realize the importance of this research. At the beginning of World War II when Vernadsky began to suspect work on the atom in the U.S. and elsewhere for military reasons, he insisted that the Russian Government move quickly on the matter, and was initially the organizer of the effort. As the program moved closer to weapons development, Vernadsky was effectively cut out of the program, the authorities viewing the ageing scientist as still something of a dissident and therefore not entirely trustworthy.

Indeed, although a patriotic Russian even in Soviet times, Vernadsky never accepted the tenets of dialectical materialism. As the Bolshevik regime in the late 1920s attempted to take over the Academy of Sciences and bring the old "gray beards" under strict supervision by the orthodox Marxists, Vernadsky led the fight to maintain the independence—and the intellectual integrity—of the Academy and the Academicians. Needless to say, he was only partially successful. While the years following 1928 would see an influx of academics from the Party hierarchy into the Academy, Vernadsky attempted to work with those who were intellectually qualified and to limit the damage inflicted on the Academy by those who were not.

V.G.Khlopin Radium Institute

The Radium Institute in St. Petersburg.

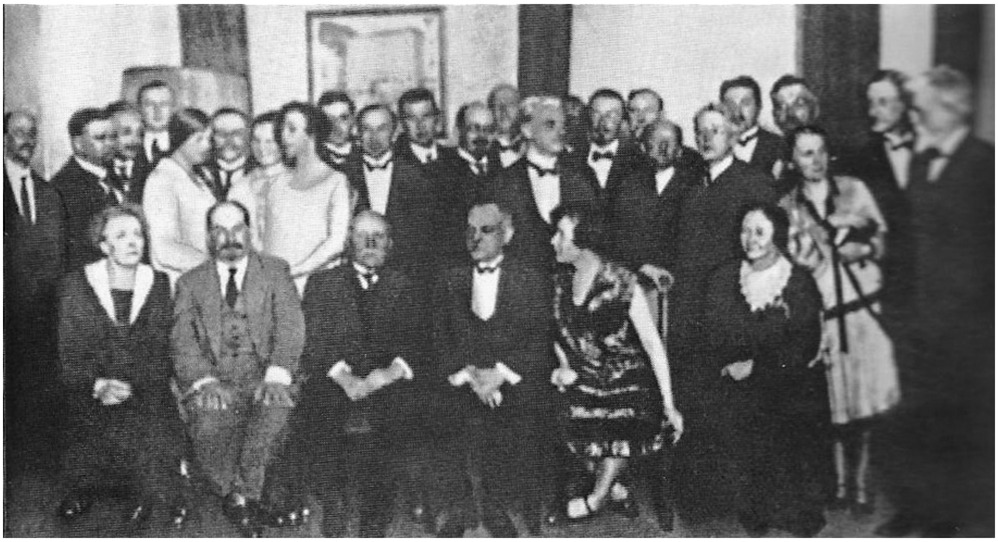
And although Vernadsky was barely tolerated by the Party apparatchiks, accused of being a "vitalist" because of his views on the question of life, he was also "protected," by higher authority from the machinations of the NKVD (the predecessor to the KGB) because of his intellectual preeminence, and continued to exert something of an influence on the scientific elites. He utilized his rather unique position to try to save many of his colleagues from being sent to the Gulag, or, if sent, to get them into a situation in which they could continue doing some form of useful scientific work, and the possibility for such work even in the Gulag became greater after World War II began. A year before he died, Vernadsky was awarded the Hero of Socialist Labor. Half of the money connected with the award, Vernadsky donated to the war effort.

U.S. National Institutes of Health

Louis Pasteur discovered chirality in living cells.

But Vernadsky is most noted for his work on the biosphere and the question of life in the universe. From the beginning he refused to accept the basic premise of abiogenesis, the idea that life proceeded from a combination of inorganic materials, oxygen, carbon, nitrogen which combined in some mysterious way, to become living matter. Vernadsky saw no scientific evidence that such a process ever occurred. He adhered to the principle enunciated by the 16th Century Italian physician, Francesco Redi, *omnium vivum e vivo*, that life only proceeds from life. This was also the conclusion from the 19th Century work of Louis Pasteur, who discovered the notion of chirality or right- or left-handedness in living tissue. This indicated that living tissue had a decidedly different structure than inorganic matter, giving more scientific grounding to the thesis of Redi.

Vernadsky was convinced


Russian Academy of Sciences

A Russian delegation visits with scientific colleagues in Berlin, 1928. Vernadsky on the far right and Albert Einstein, third from the left.

that there was no indication within geological time (which we can examine through a study of the Earth's crust), of life ever proceeding from non-life. He was also convinced that we would not find indications of abiogenesis in cosmic time either, that is, during the earlier period when Earth was forming out of its swirling vortex, although this latter era was more difficult to investigate. Secondly, given the continual exchange of matter between our Earth and the surrounding space, in the form, for instance, of cosmic radiation or cosmic particles, Vernadsky noted, life may well have been brought to us from elsewhere and, finding ideal conditions here, developed and flourished in that environment. Vernadsky urged the examination of material from other planets, such as meteorites, in order to determine their chemical composition, and possibly, if there were also there signs of life. Vernadsky held to his thesis despite the consistent attempts by orthodox Marxist scholars, who deemed Vernadsky's attacks on the theory of abiogenis undermining the "materialistic" foundations of their own "dialectical materialism," to disprove it. The career of science "apparatchik," Alexander Oparin was carefully cultivated by Vernadsky's enemies in order to discredit Vernadsky's hated "vitalism." The "fellow traveler'' networks of Bertrand Russell and J.B.S. Haldane helped to make Oparin's 1936 book *The Origin of Life* the bible of the abiogensists. Oparin was feted by these Western circles as a great scientific thinker in spite of the key and very public role he played in the Soviet Union in promoting the frauds of that notorious fraud, Trofim Lysenko, who led a campaign to eliminate some of the most important scientists in the Soviet Union.

Vernadsky also was the first to recognize the absolutely essential role of the biosphere, i.e. the total aggregate of living matter on Earth, in the development of the Earth's upper crust and atmosphere and stratosphere. With the appearance of Man, however, Vernadsky saw an entirely new dimension in the history of the biosphere in the changes wrought through the productive activity of Man. Just as the biosphere is characterized by a steady increase in its energy throughput as it develops and subsumes the Earth, so also does the activity of Man begin to develop its own characteristic form of "energy" which assumes a predominant role in the biosphere and transforms it.

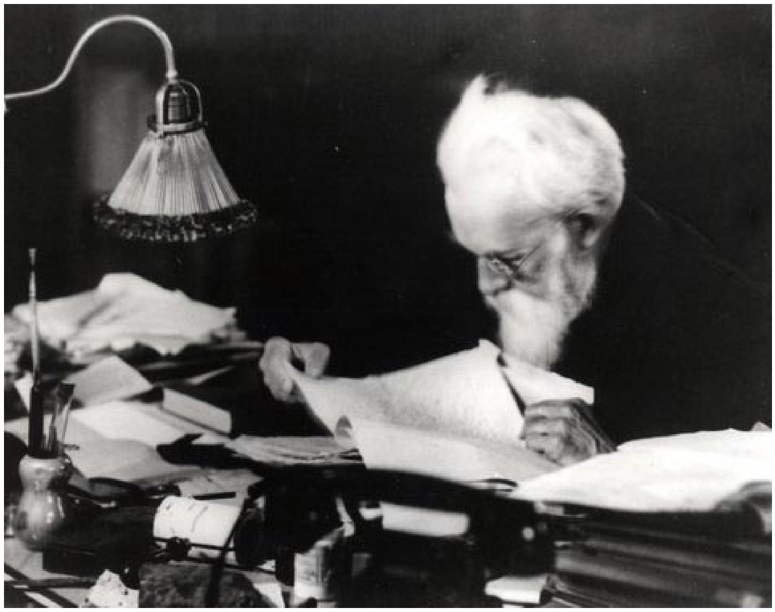
Vernadsky called this new era with the development of man, the noösphere, after the Greek term noos (or mind), to distinguish it from the biosphere per se. The term was coined by Eduard LeRoy, who, together with Jesuit palaeontologist, Teilhard de Chardin, attended Vernadsky's geochemistry lectures in Paris at the Sorbonne in 1924. Vernadsky adopted the term as his own to depict the stage of the biosphere characterized by the preponderant activity of man.

Vernadsky felt that now in the 20th Century, with Einstein's discovery of relativity and with the mastery of atomic energy, man was in the process of taking a tremendous leap forward in the development of the noösphere, putting him on the verge of extending his reach into the surrounding universe. His last great works, the unfinished "The Chemical Structure of the Biosphere and Its Environs" and "Scientific Thought As A Planetary Phenomenon" both written between 1931 and 1944, were to be the final word of his mature thought. Lamentably, the first work, more broad-ranging than the latter, was to have a third section devoted exclusively to the notion of the noösphere, but Vernadsky was not able to conclude the work before his death. Given that critical lacuna, the second work, "Scientific Thought As a Planetary Phenomenon" from which this chapter is taken, undoubtedly represents Vernadsky's most extensive elaboration of the notion of the noösphere.

The chapter appears in the section of the book entitled

New Scientific Knowledge and the Transition from the Biosphere to the Noösphere. In it, Vernadsky traces the development of man from his first appearance as man with his mastery of fire, the first instance that we are aware of, in which man takes direct control of a force of nature. Vernadsky indicates here also the new possibilities for man's role in the universe, the possibility of extending his activity into space and possibly to other planets. It is imbued with a tremendous sense of optimism, optimism which, by the way, never abated, even in the face of the horrors of World War II.

Quite simply, Vernadsky understood that there existed in the universe a principle of development, which, with the development of man and the new-found role of man's reason, expressed itself in the necessity for continued progress. While a great deal of distortion of the thrust of Vernadsky's thought has been introduced into the public domain over the last several decades by the Green movement's "adoption" of Vernadsky as some form of "ecologist," it is hoped that the ideas expressed clearly by Vernadsky in the present work will lay to rest any doubts about where he stood in that respect, firmly behind the commitment to the scientific and technological development by means of which man becomes ever more the master of his universe.



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Vernadsky in his study around the time of the writing of "Scientific Thought As A Planetary Phenomenon."

The Transition From the Biosphere To the Noösphere

by Vladimir Vernadsky

Excerpt from "Scientific Thought As a Planetary Phenomenon"

Chapter VII

100.

The sciences concerned with the biosphere and its objects, that is, all of the humanities without exception, the natural sciences in the proper sense of the term (botany, zoology, geology, mineralogy, etc.), all the technical sciences, — applied sciences broadly understood — appear as areas of knowledge, which are the most accessible to the scientific thought of Man. Here we have concentrated millions upon millions of continuous scientifically established and systematized facts, which are the result of organized scientific labor, and which inexorably increase with each new generation, rapidly and consciously, since the 15th to 17th centuries.

In particular, the scientific disciplines dealing with the structure of the instruments of scientific cognition, indissolubly linked to the biosphere, may be scientifically viewed as a geological factor, a manifestation of the manner in which the biosphere is organized. These are sciences dealing with the "spiritual" creativity of the human individual in his social environment, the sciences of the brain and of the sense organs, of the problems of psychology or logic. These condition the quest for the fundamental laws of Man's scientific cognition, that is, those powers which have transformed the biosphere encompassed by Man into a natural body, new in its geological and biological processes, into a new state, the noösphere,[1] consideration of which I will turn to below.

Its creation, beginning intensively (in the measure of historical time) some tens of thousands of years ago, was an occurrence of extreme importance in our planet's history, connected above all with the growth of the science of the biosphere, and was definitely not by chance.[2]

We may therefore state that the biosphere represents the fundamental sphere of scientific knowledge, although only now are we on the point of distinguishing it from its surrounding reality.

101.

It is clear from the foregoing that the biosphere is equivalent to "nature" in the ordinary sense of the term, as this term is used in the deliberations of the naturalist and in philosophical discussions, where it does not refer to the Cosmos at large but rather to phenomena contained within the bounds of Earth. In particular, it corresponds to the naturalist's nature.

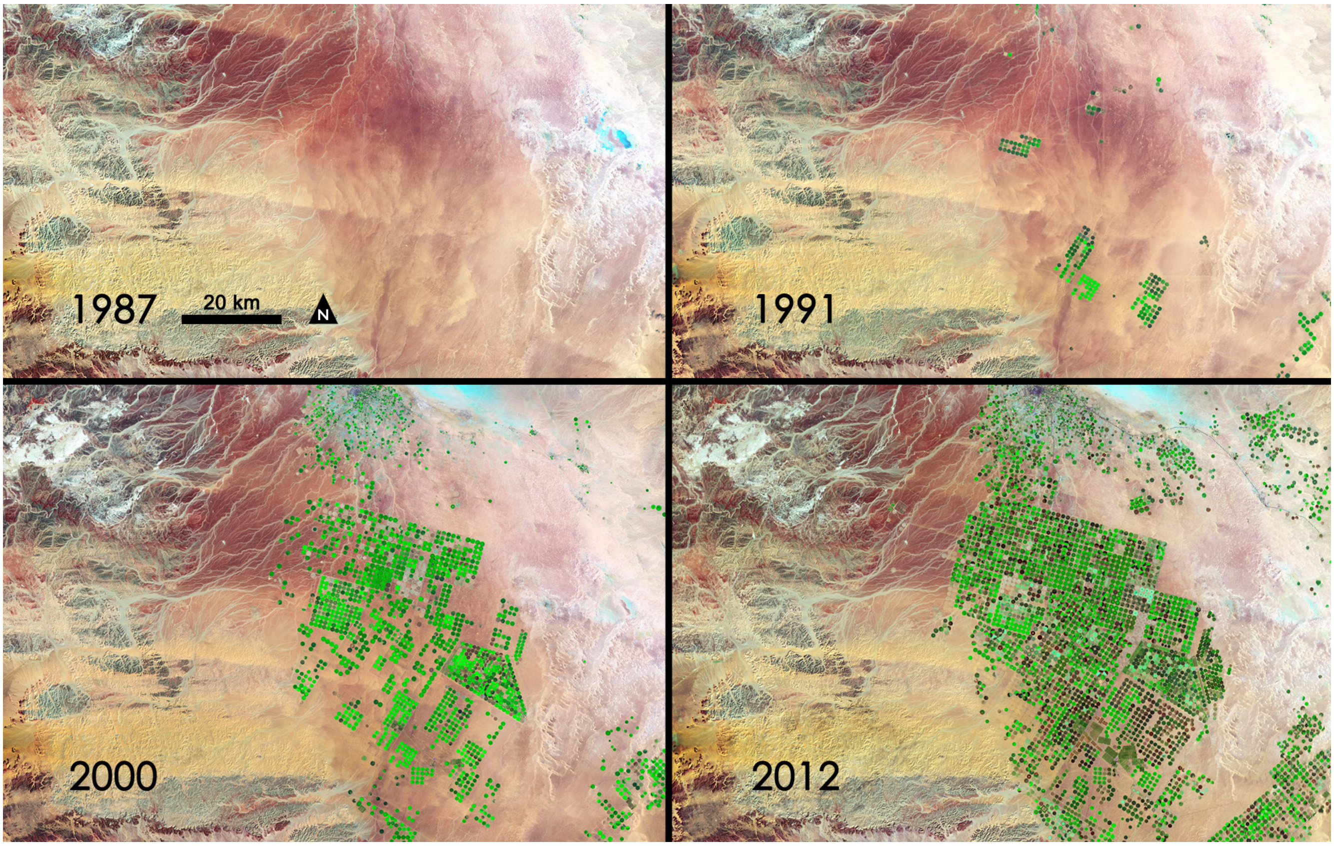
Not only is this "nature" not amorphous and without form, as was thought for centuries, but rather it possesses a determined, well-defined structure,[3] which, as such, must be reflected and taken into consideration in all the conclusions and deductions relating to nature.

In scientific investigations it is especially important not to forget this and to examine it, since unconsciously, sci-

1. *E. Le Roy. Les origines humaines et l'évolution de l'intelligence, III. La noosphère et l'hominisation*. Paris, 1928, pp. 37-57

2. I will return later to that process. Here I will merely indicate the thought of Le Roy: "Deux grands faits, devant lesquels tous les autres semblent presque s'évanoir, dominent donc l'histoire passée de la Terre: la vitalisation de la matière, puis l'hominisation de la vie." — op. cit. p. 47

3. That "structure" is quite distinctive. It is not a mechanism nor is it something stationary. It is dynamic, ever changing, mobile, in each instance changing itself and never returning to a previous form of equilibrium. The closest to it is the living organism, distinguishing itself, however, from it in its physical-geometrical state of its space. The space of the biosphere is heterogeneous in its physical-geometrical dimension. I think, that it is proper to assign to that structure a specific notion of organization.



NASA

The energy of human culture: The greening of the desert near the city of Tubarjal in Saudi Arabia.

entists and scholars, when contrasting the human individual with nature, are overwhelmed by the grandeur of nature against the human individual.

But life in all its manifestations, including the activity of the human individual, radically transforms the biosphere to the degree that not only the aggregate of indivisible life, but even some problems of the solitary individual person in the noösphere, cannot remain without consideration in the biosphere.

102.

Living nature is the fundamental trait of the manifestation of the biosphere, and by this clearly distinguishes itself from the Earth's other envelopes. The structure of the biosphere is characterized first and foremost by life.

We see below that there lies, in a number of aspects, an unbridgeable gulf between the physical-geometric properties with regard to the weight and quantity of the atoms in living organisms—in the biosphere they are manifested in the form of their aggregates-living substance, and such properties, in inert matter, which comprises the overwhelming part of the biosphere. Living matter is the bearer for, and creator of, free energy, not existing to such a degree in any one of Earth's envelopes. This free energy—biogeochemical energy[4]—embraces the entire biosphere and fundamentally determines its entire history. It stimulates and radically transforms the intensity of the migration of the chemical elements which compose the biosphere and determines its geological significance.

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4. The concept of biogeochemical energy came to me in 1925 in a still unpublished paper for the L. Rosenthal Fund (the fund is no longer in existence). This fund gave me the opportunity to quietly devote myself to this work over the course of two years. A series of articles and books from this research are therefore in print:
- Biosfera. Leningrad, 1926, pp.30-48;
- Etudes biogéochimiques, 1. Sur la vitesse de la transmission de la vie dans la biosphère.—*Isvestiia* AH, 6 series, 1926, v. 20, No. 9, pp. 727-744;
- Etudes biogéochimiques. 2 La vitesse maximum de la transmission de la vie dans la biosphère.—*Izvestiia* ANs, series 6, 1927, V. 21, No. 3-4, pp. 241-254;
- O razmnozhenii organizmov i ego znachenii v mekhanizme biosfery. *Izvestiia* AN, series 6, 1926, V. 20, No. 9, pp. 697-726, No. 12, pp.1053-1060;
- Sur la multiplication des organismes et son role dans le mécanisme de la biosphère, pp. 1-2, *Revue générale des sciences pures et appliquées*. Paris, 1926, t. 37, N 23, pp. 661-668; pp. 700-708;
- Bakteriofag I skorost' peredachi zhizni v biosfere, *Priroda*, 1927, No. 6, pp. 433-446.

During the past ten thousand years, a new form of this energy has been created within the realm of living substance, even more intense and complex, and rapidly growing in importance. This new form of energy, associated with the vital activities of human societies, of the genus *Homo* and other closely related genera (hominids), while preserving the expression of ordinary biogeochemical energy, brings about simultaneously new forms of migration of chemical elements, which in their diversity and power leave the ordinary biogeochemical energy of the living matter of the planet far behind.

This new form of biogeochemical energy, which might be called the energy of human culture or cultural biogeochemical energy, is that form of biogeochemical energy, which creates at the present time the noösphere. Later I will return to a more detailed exposition and analysis of our understanding of the noösphere. But at the moment it is only necessary for me to present a brief outline of its manifestation on our planet.

This form of biogeochemical energy is proper not only to *Homo sapiens,* but to all living organisms.[5] However, among these, this energy appears insignificant compared with ordinary biogeochemical energy, and is barely noticeable in the balance of nature, and then only on the scale of geological time. It is associated with the mental activity of organisms, with the development of the brain in higher forms of life, and only with the appearance of reason do its effects produce the form of transition of the biosphere into the noösphere.

Its manifestation in the predecessors of Man was probably developed over the course of hundreds of millions of years, but it was able to express itself as a geological force only in our time, when *Homo sapiens* has embraced the entire biosphere with his life and cultural work.

103.

The biogeochemical energy of living matter is determined primarily by the reproduction of organisms, by their unremitting endeavor (determined by the energetics of the planet) to achieve a minimum of free energy — determined by the fundamental laws of thermodynamics corresponding to the existence and stability of the planet.

It is expressed in the respiration and alimentation of living organisms, by "the laws of nature," which to the present time had not found a mathematical expression, although the task of discovering such was clearly posed already in 1782 by Christian Wolff at the former St. Petersburg Academy of Sciences.

Certainly, this form of biogeochemical energy is also characteristic of *Homo sapiens*. For Man it is, as for all other organisms, a "species characteristic,"[6] and seems to us invariable in the course of historical time. In other organisms, there is another form of "cultural" biogeochemical energy, which is unchangeable or only slightly so. This other form is manifested in the everyday life or technical conditions of life of the organisms—in their movements, in their daily existence and the construction of their habitats, in their displacement of other organisms in their environment, etc. As I have already noted, this energy makes up only an insignificant part of their biogeochemical energy.

With Man, however, the form of biogeochemical energy connected to reason grows and expands with time, rapidly moving to the fore. This increase is possibly related to the growth of reason itself—a process which seems to occur very slowly (if at all) but is chiefly connected to its honing and deepening in using it to consciously transform the social environment, and is especially due to the growth of scientific knowledge.

I shall proceed from the fact that in the course of hundreds of thousands of years, *Homo sapiens* skeletons, including the craniums, do not provide a basis for considering them as belonging to a different species of Man. This is assumed only on the condition that the brain of Paleolithic Man was not in some fundamental way structurally distinct from the brain of contemporary Man. At the same time, there can be no doubt that the mind of man during the Paleolithic period for that particular species of *Homo* cannot bear comparison with the mind of modern man. Hence it follows that reason is a complex social structure, erected similarly for contemporary Man, as well as for Paleolithic Man, on the same neural substrate, but in different social circumstances that formed over time (essentially over space-time).

Its explicit transformation is a fundamental element leading ultimately to the transformation of the biosphere into the noösphere, first and foremost, through the creation and growth of the scientific understanding of our surroundings.

104.

The creation on our planet of cultural biogeochemical energy appears to be a fundamental fact of its geological history. The way was prepared in the course of all geological time. The fundamental determining process here is the maximum expression of the human mind. But in essence this is inextricably linked with the totality of all biogeochemical energy of living matter.

By means of the migration of atoms in living processes, life bundles together into a single whole all the migrations

5. V. I. Vernadskii. *Biosfera*, pp. 30-48; O razmnozhenii organizmov i ego znachenii v mekhanizme biosfera.—op. cit., No. 9, pp. 697-726, pp.1053-1060.

6. Regarding species characteristics, See: V. I. Vernadskii. Considerations générales sur l'étude de la composition chimique de la matière vivante.—*Trudy Biogeokhimicheskoi laboratorii*, T. 1, 1930, pp. 5-32.

of atoms in the non-living matter of the biosphere.

Organisms are alive only until the material and energetic exchange between them and the surrounding biosphere ceases.[7] In the biosphere certain grand chemical circulatory processes of atomic migrations appear, in which living organisms are involved, as a lawful inseparable, and often fundamental, part of the process. These processes remain unchanged in the course of geological time: for instance, the migration of the atoms of magnesium forming into chlorophyll has gone on uninterruptedly for at a least two billion years through countless genetically interconnected generations of green organisms. Living organisms, continuously and inseparably connected to the biosphere through such migrations of atoms alone, constitute a lawful part of its structure.

This must never be forgotten in our scientific study of life and in our scientific judgments regarding life's manifestations in Nature. We must not neglect to take into account that this indissoluble material and energetic link of living organisms with the biosphere—a link of a completely distinct character, which is "geologically eternal," and may be expressed with scientific accuracy—is always present in any of our scientific approaches to living things and must be reflected in all of our logical conclusions and deductions concerning them.

Coming to the study of the geochemistry of the biosphere, we must above all precisely estimate the logical importance of that connection, which must necessarily enter into all of our constructs regarding life. It is independent of our will and cannot be excluded from our experiments and observations; it must always be taken into account as something fundamental that is inherent in living things.

In this way the biosphere without exception must be reflected in all of our scientific judgments. It must be manifest in every scientific experiment and observation—and in all a human individual's deliberations, and in all speculation, from which a human individual—even in his thoughts—cannot refrain.

The mind can therefore be manifest to the maximum degree only under conditions of the maximum development of the fundamental form of human biogeochemical energy, that is, under the condition of man's maximum degree of reproduction.

105.

The potential possibility of the expansion over the surface of the entire planet by the multiplication of a single organism, of a single species, is proper to all species, since, for all of them the law of reproduction is expressed in one and the same form, in the form of a geometrical progression. I have long emphasized the fundamental significance of this phenomenon for biogeochemistry,[8] and I shall return to it in its proper place in this book.

It is evident that the phenomenon of the expansion over the entire surface of the planet by a single species developed widely in the case of aquatic life such as microscopic plankton in lakes and rivers, and some forms of microbes, essentially also aquatic, on the cover of the planet's surface, and disseminated through the troposphere. For larger organisms, we observe this almost in full measure with certain plants.

For Man this begins to be seen in our time. By the 20th Century the entire globe and all the seas have been encompassed by Man. Owing to the progress of communications, mankind is able to be in continual contact with the entire world, nowhere solitary or helplessly lost in the immensity of Earth's nature.

Now the Earth's human population has reached the previously unprecedented figure of nearly two billion people, despite the losses incurred by wars, starvation and disease, which continuously afflict hundreds of millions of people, and which have seriously retarded the course of that process. It will require, however, only an insignificant amount of time in geological terms, barely more than a few hundred years, for such relics of barbarism to cease. This could of course be accomplished even now: the possibility lies already within Man's grasp, and a will informed by reason will inevitably embark on this path, since it corresponds to the natural thrust of the geological process. This is even more the case as the opportunities for doing this are rapidly, almost spontaneously, increasing. The real significance of the popular masses, which have endured these sufferings more than anyone, is irrepressibly growing.

The number of people inhabiting our planet began to increase approximately 15,000 to 20,000 years ago, when Man became less constrained by the shortage of food with the development of agriculture. Presumably at that time, around 10,000-18,000 years ago, the first leap in man's reproduction took place.[9] G.F. Nicolai (in 1918-1919)[10] attempted to quantitatively determine the actual multiplication of Man and the development of agriculture, that is, Man's real colonization of the planet. In his

7. The complete absence of exchanges in dormant forms of life can not yet be considered verified. It is extremely slow—and perhaps in some cases of atomic migrations actually absent—this becomes noticeable only in geological time..

8. Regarding the speed of the transmission of life, see: V. I.. Vernadskii. *Biosfera*, p. 37-38; Also Etudes biogéochimiques. 1. Sur la vitesse de la transmission de la vie dans la biosphere.—op.cit., N 9, pp 727-744; Also *Biogeokhimicheskie ocherki*, (1922-1932) M.-L. 1940, pp. 59-83.

9. V.G. Childe. *Man Makes Himself.* London, 1937, pp. 78-79.

10. G.F. Nikolai. *Die Biologie des Krieges*. 1.—Betrachtungen eines naturforschers den Deutschen zur Besinnung. Band 1. Zurich, 1919. p. 54.

Stefan Kühn

A new form of energy connected to the atomic nucleus. Nuclear reactors in Cattenom , France.

calculations, which encompassed the entire land-mass of the globe, there were 11.4 people per square kilometer, which constituted 2.10% to 4% of the possible colonization. Taking into account the energy received from the Sun, agriculture makes it possible to support 150 people on one square kilometer, that is, on the entire land area of the globe you could support a population of 22.5 billion individuals, that is, 22-24 times the number that now inhabit it.[11] But Man obtains energy for nourishment and subsistence not only from agricultural labor. Taking into consideration that possibility, Nicolai made a rough estimate that, starting from the historic epoch begun in our time, utilizing new energy sources, Earth could support a population of 3 trillion people, that is, more than ten million times greater than the present population. Now after more than 20 years have passed since Nicolai made his calculations, these figures ought to be greatly increased since Man may now use a source of energy to which Nicolai in 1917-1919, gave no thought: namely, the energy connected to the atomic nucleus. We should now more simply say that the source of energy subject to Man's reason, in this energetic epoch of the life of Man on which we have now embarked, is practically unlimited. From this it is also clear that cultural biogeochemical energy possesses the same quality. In the calculations of Nicolai in his day, machines increased the energy of Man more than tenfold. We cannot now give a more precise figure, yet recent estimates by the American Geological Committee indicate that hydroelectric power, utilized now over the entire globe, had reached, by the end of 1936, the level of 60 million horsepower: Within 16 years it had increased by 160 percent, chiefly in North America.[12] As a result, we must increase the calculations of Nicolai by more than one and a half times.

Actually, all of those calculations of the future, expressed in numbers, are not significant, since our knowledge of the energy available to mankind may be said to be rudimentary. Certainly the energy available to Man is not an unlimited quantity, as it is limited by the dimensions of the biosphere. These also define the limits of cultural biogeochemical energy.

We will see that there is even a limit to the fundamental biogeochemical energy of mankind-namely, the speed of the transmission of life, the limit of the reproduction of Man.

The speed of colonization, the quantity V, essentially considered by Nicolai, is based on actual observations of the colonization of the planet by Man under clearly inauspicious conditions of life. In addition, we will furthermore see that there exist some phenomena in the biosphere yet unknown to us, but powerful in a given geological era and under certain conditions of the ecosystem, which lead to a stationary maximum number of individuals per hectare.

106.

It was only at the beginning of the 19th Century that we were able to determine with any accuracy the number of human beings living on the planet. The number was arrived at with a great degree of possible error. In the last 137 years, our knowledge has increased considerably, but it still does not achieve the accuracy required by modern science. For earlier periods, the figures are only provisory. All of this aids us, however, in understanding the underlying process.

Regarding this, the following facts may be of some significance.

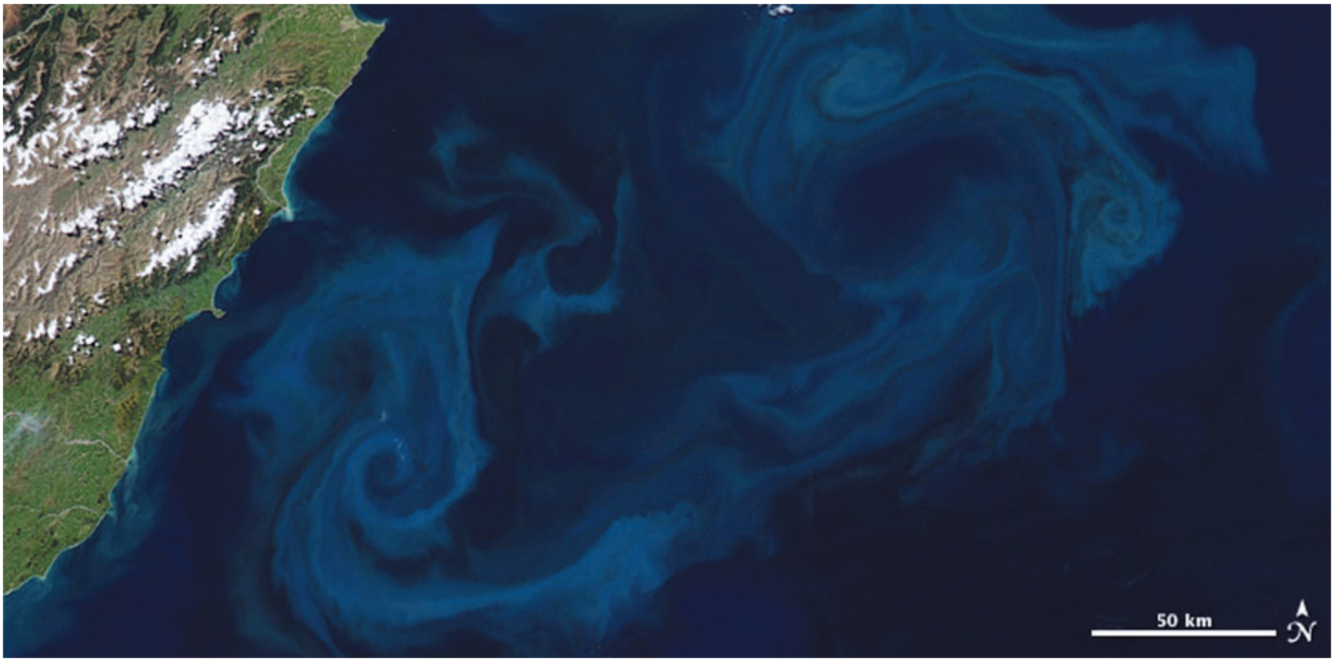
The number of people in the Paleolithic period probably reached a few million. Presumably this developed from one single branch. But the opposite may also be true.[13]

During the Neolithic period, there were probably some tens of millions of people on the entire surface of the

11. G.F. Nikolai. op.cit., p. 60.

12. Water-Power of the World (News and Views).—*Nature*, 1938, v. 141, N 3557, p. 31.

13. See Le Roy. op.cit.



NASA

The formation of phyloplankton off the coast of New Zealand, Oct.2009

Earth. It is possible to assume that even in historical time, the population did not reach 100 million, or perhaps slightly more. [14]

For 1919, G.F. Nicolai surmised that the population of the planet increased annually by 12 million people, that is, a daily increase of approximately 30,000 people. According to the critical report of Kulischer (1932),[15] world population in 1800 reached 850 million people (A. Fisher gives an estimate equal to 775 million). We can estimate the population of the white race in the year 1000 A.D. as being equal to 30 million in all, in 1800, 210 million, and in 1915, 645 million. The entire population in 1900, according to Kulischer, was around 1,700 million, but according to A. Hettner (1929),[16] the number was 1,564 million in 1900 and 1,856 in 1925.

Evidently in our own time this number has reached around 2 billion people, more or less. The population of our own country (around 160 million people) makes up around 8% of the total world population. The total population is rapidly increasing and, apparently, the percentage of our country's population is increasing relatively, as its increase is greater than that of the world average. In general, we should expect by the end of the century a significant increase exceeding 2 billion people.

107.

The multiplication of organisms, that is, the manifestation of biogeochemical energy of the first type without which there is no life, is inseparable from Man. But Man, from the very moment that he distinguishes himself from the aggregate of other life-forms on the planet, already possesses the tools, albeit rather primitive ones, which allow him to increase his muscle-power and is the first expression of contemporary machinery which distinguishes him from other living organisms. The energy which sustained him was, however, produced through the alimentation and respiration of his own organism. It is likely that already for hundreds of thousands of years as Man— the genus *Homo,* and his predecessors—he possessed tools made out of wood, bone and stone. Slowly, in the course of many generations, he developed the ability to fashion and utilize those tools, honing that capability, reason in its initial manifestation.

Those tools had been observed already in the earliest Paleolithic period, 250-500,000 years ago.

In that period, a significant part of the biosphere experienced a critical time. It seems that already at the end of the Pliocene period, abrupt changes occurred—in the water and heat regime of the biosphere, beginning and continually developing during the period of glaciation. We are apparently still living in the period of the last gla-

14. B.P. Weinberg. *Twenty thousand years from the beginning of the elimination of the oceans. Review of the History of Mankind from a Primitive State to the Year 22,300. (A scientific fantasy)*. Sibirskaya priroda. Omsk, 1922, No. 2 p. 21 (assumes a population of 80 million at the beginning of our era).

15. A. and E. Kulisher. *Kriegs-und Wanderzüge. Weltgeschichte als Völkerbewegung*. Berlin—Leipzig, 1932. p. 135

16. A. Hettner. *Der Gang der Kultur Uber die Erde.* 2nd edition, revised and expanded. Aufl. Leipzig-Berlin, 1929. p. 196

ciation's retreat phase, although we don't know whether this is permanent or merely temporary. In that half million years, we see sudden fluctuations in the climate; relatively warm periods—lasting tens and hundreds of thousands of years—gave way in the northern and southern hemisphere to periods, when large masses of ice slowly moved (measured in historical time), reaching the thickness of a kilometer, for instance, in the vicinity of Moscow. These disappeared from the Leningrad region 7000 years ago,[17] but still envelop Greenland and Antarctica. Apparently, *Homo sapiens* or his closest predecessors appeared not long before the onset of that glacial period, or in one of its warmer episodes. Man survived the severe cold of that period, possibly due to the great discovery that had been made in the Paleolithic age— the mastery of fire.

Man's discovery of fire was the first sign of the noosphere

That discovery was made in one, two, or possibly more places, and slowly spread among the peoples of the Earth. It seems that we are dealing here with a general process of great discoveries, in which it is not the mass action of mankind, smoothing and refining the details, but rather the expression of separate human individuals. As we'll later see, we can track this phenomenon more closely in very many cases nearer to our own era.

The discovery of fire presents the first instance in which a living organism takes possession of, and masters, one of the forces of nature.[18]

Undoubtedly this discovery lies, as we now see, at the foundation of mankind's subsequent future increase and of our present powers.

But that increase occurred extraordinarily slowly, and it is difficult for us to imagine the conditions under which it may have occurred. Fire was already known to the ancestors or the predecessors of that species of hominid, which established the noösphere. The recent discovery in China reveals to us the cultural remains of Sinanthropus, which indicate an extensive utilization by him of fire, apparently long before the last glacial period in Europe, hundreds of thousands of years before our time. We have at present no reliable data as to how that discovery was made. Sinanthropus already possessed reason, had crude tools, used speech, and conducted funereal rites. He was already Man, but was distinguished from us by a number of morphological characteristics. We don't exclude the possibility that this was one of the ancestors of the present population of China.[19]

108.

The discovery of fire is all the more remarkable in that the appearance of fire and light in the biosphere before Man was a relatively rare phenomenon and generally occurred when it encompassed a large space, as in forms of "cold light," which are expressed in heavenly luminescence, polar light, silent electric discharges, stars and planets, or luminescent clouds. But only the Sun, that source of life, brightly displays simultaneously both light and heat, illuminating as well as warming the dark planet.

Living organisms for a long time produced a form of "cold light." This was seen in such imposing phenomena as bioluminescent oceans, which encompass areas usually stretching hundreds of thousands of square kilometers, or in the luminescence of the ocean's depths, the significance of which is only now beginning to be understood. Fire, accompanied by high temperatures, was manifest in local phenomena, rarely encompassing a vast expanse as, for example, in volcanic eruptions.

But these phenomena, grand by human standards, obviously owing to their great destructive force, in no way assisted in Man's discovery of fire. Man had to have sought it in natural phenomena closer to him, and in less unusual and dangerous forms than volcanic eruptions, which even now exceed in their magnitude, the powers of contemporary Man. We are only now beginning to achieve its practical utilization in circumstances far beyond the power or the imagination of Paleolithic Man.[20]

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17. Now we know that in the environs of Leningrad, the ice disappeared about 12 thousand years ago. (Ed.)

18. V.G. Childe. *Man Makes Himself*. London, 1937, p. 56. Compare: J.G. Frazer. *Myths of the Origin of Fire*. London, 1930.

19. See: On the technology of Sinanthropus and the use of fire by him, see: B.L. Bogalevskii. The technology of primitive-communistic societies.—*Istoriia tekhniki*, vol. 1, ch. 1, Moscow-Leningrad, 1936, pp. 26-27. Fire was also used by Pithecanthropus which lived earlier in the very beginnings of the Pleistocene, scarcely more than 550 thousand years ago. Compare B. L Bogalevskii, Ukaz. soch., pp. 11, 67. The use of fire for Pithecanthropus is still not proven, but is highly probable.

20. Only in the 20th Century in Larderello on the initiative of Le Conte, did Man obtain, with the help of drilling, superheated vapor (140 degrees C) as a source of energy. Still later in Soffioni (New Mexico) and Sonoma that method was improved. Before his death, Parsons was working on a practical design to achieve, by drilling, an inexhaustible source of energy, at least from the point of view of humanity, from the internal heat of the Earth's crust. An analogous attempt of obtaining energy from the cold depths of the ocean by French academic Claude did not succeed in doing so only because of some acts of criminal hooliganism in 1936. We doubtless have in the hands of Man in these developments a practically inexhaustible force.

He would have had to have sought sources of heat and fire in surrounding everyday phenomena; in the places where he lived—in the forests, on the steppes, in the midst of a living nature with which he lived in close intercourse (now long forgotten). Here he would encounter fire and heat in non-threatening forms in a succession of commonplace phenomena. These were, on the one hand, fires in which living matter, living and dead, was burned. These were precisely those sources of fire used by Paleolithic Man.

He burned trees, plants, bones, the very same that fed the fires around him, independent of his will. Until Man began to use it, fire was caused by two very different sources. On the one hand, lightning discharges caused forest fires or ignited dry grass. Even now Man suffers from such fires. The conditions of nature during the glacial period, particularly during the interglacial period, may have provided even more favorable conditions for such thunderstorm phenomena. Yet there was also another source for the independent occurrence of fire.

These were the life-activities of the lower organisms which led to the fires in the dry steppes,[21] to the burning of layers of coal deposits, to the burning in peat bogs, which endured for several generations and provided convenient opportunities for obtaining fire. We have direct evidence of such coal fires in the Altai region, in the Kuznetz basin, where they occurred in the Pliocene and in the post-Pliocene period, but where they continued into the historical period, and where they must be considered still occurring now. The causes of these fires has to this day not been fully clarified, but everything indicates that we here are hardly dealing with the result of a purely chemical process of spontaneous combustion, that is, one caused by the intensive oxidation of fractured coal by oxygen in the air, or by the spontaneous combustion of the sulphuric compounds of iron produced by the heat developing during oxidation of the coal.[22]

More probable is the existence of biochemical processes connected to the life-activities of thermophilic bacteria. Regarding peat bogs, we even have during the recent period the direct observations of B.L. Isachenko and N. I. Malchevskoy.[23]

These phenomena now require more careful study.

109.

Such warm regions, winter and summer, as well as areas with hot springs, were blessings of nature for Paleolithic Man, who also had to utilize them as they were, or have recently been, utilized by tribes or peoples that we still find living in a Paleolithic state.

With the great powers of observation of Man in that era and with his close proximity to nature, such areas undoubtedly attracted his attention, and would have been utilized by him, particularly in the glacial period.

It is interesting that among the instincts of animals we can observe the use of those same biochemical processes. This is seen in the family of cocks, the so-called brush turkeys, or the big-nosed megapodes of Oceania and Australia, which utilize the heat of fermentation, that is, a bacterial process, for hatching the fledging out of the egg, building large piles of sand or earth and mixing it with strongly rotting organic remains.[24] Those piles can reach 4 meters in height and a temperature of not under 44 degrees Centigrade. These seem to be the only birds possessing such an instinct.

It is possible that ants and termites purposefully raise the temperature of their dwellings.

But these feeble endeavors cannot be compared with that planetary revolution produced by Man.

Man utilizes as a source of energy, fire, the products of life—dried vegetation. Many myths about its discovery have been coined and kept in circulation.[25] But most typical is that Man utilized methods for creating it which would never have been observed by him in the biosphere until his discovery of it. The most ancient technique seems to have been the transfer of muscle-power into heat (powerfully rubbing together dry objects), and creating sparks, and catching them from certain rocks. The complex system of maintaining fire after all came into ex-

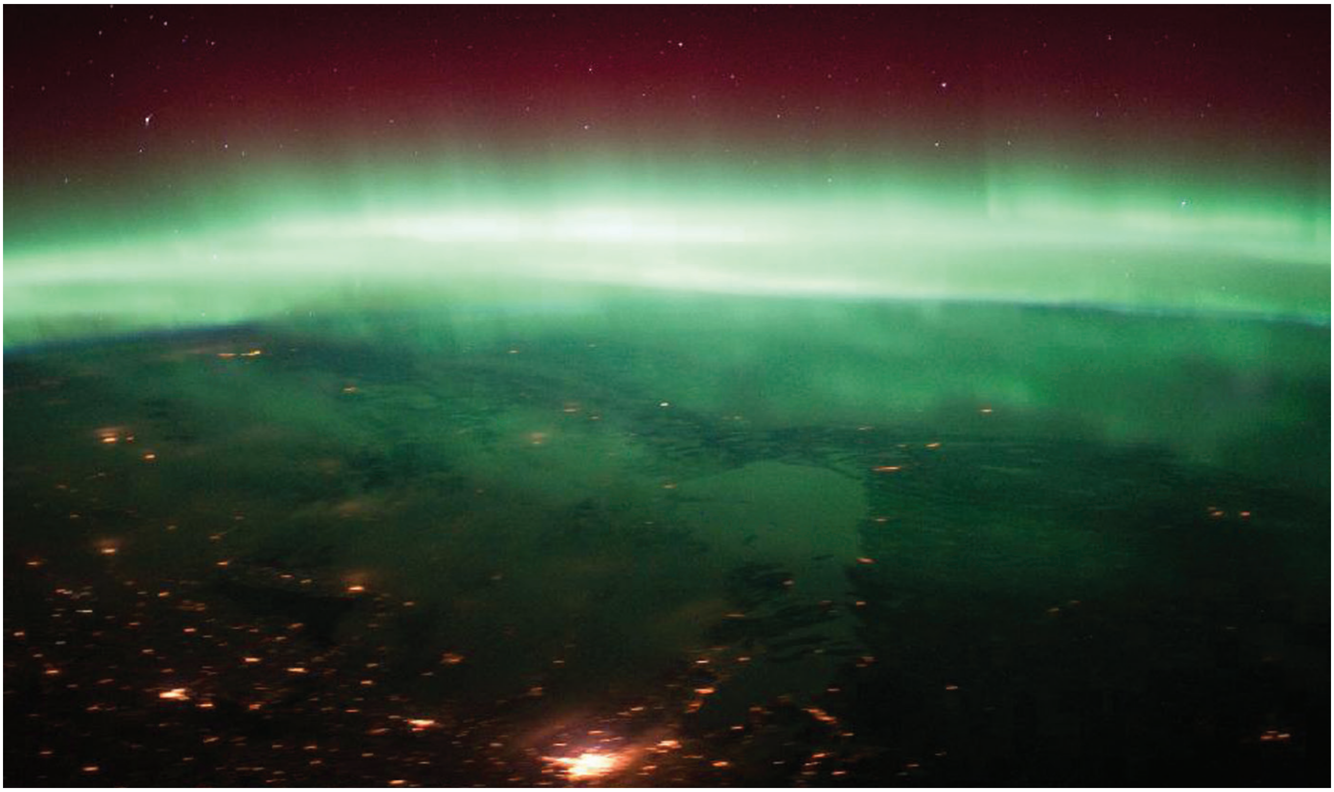
21. Some people deny that spontaneous combustion of dry grass in the steppes, pampas, and forests actually occurs. Nowadays fires are nearly always caused by Man, but there are occasions which, it seems, indicate without a doubt the possibility of a process of spontaneous combustion in the steppes as a result of the direct activity of the Sun. The causes of the phenomenon are not clear. Concerning such events, see: E. Poepping. *Reise in Chili, Peru und auf dem Amazonenstrom wahrend der Jahre 1827-1832*, Bd. 1. Leipzig, 1835, p. 398. G.D. Hale Carpenter. *A Naturalist on Lake Victoria.—With an Account of Sleeping Sickness and the Tse-tse Fly*. London, 1920, pp. 76-77.

22. See: M. A. Usov. *Composition and tectonics of the deposits of the Southern region of the Kuznetsk coal basin*. Novonikolaevsk, 1924, p. 58; idem, Subterranean first in the Prokpyevsk region—a geological process, *Vestnik Zapadno-sibirskogo geologo-razvedochnogo trests*, 1933, no. 4, p. 34; and V.A. Obruchev. Subterranean fires in the Kuznetsk basin, Priroda, 1934, no. 3, pp. 83-85. Already I.F. Hermann, who discovered the Kuznetz coal basin, indicated in 1796 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*. St. Petersburg, 1793, pp. 376-381. Compare: V. Yavorsky and L.K. Radugina. Die Erdbraende im Kuznetzk Becken und die mit ihnen verbundenen Erscheinungen, *Geologische rundschau*. 1933, Hf. 5; V.I. Javorsky and L.K. Radugina.; Coal fires in the Kuznetsk basin and the related phenomena, *Gornyi zhurnal*, 1932, no. 10, pp. 55. [In Russian]

23. See: B.L. Isachenko and N.I. Mal'chevskaya. Biogennoe samorazogrevanie torfianoi kroshki, *Doklady* AN, 1936, T. IV, No. 8, p. 364.

24. See: A. Brehm. *Life of animals*. 4th edition, completely revised and considerably enlarged by Professor Otto Zur-Strassen. An authorized translation translation edited by a professor of the Psycho-neurological Institute for Women and the St. Petersburg M. N. Knipovich Medical Institute for Women. Vol 7. Birds. St. Petersburg, 1912. p. 15.

25. See: I.G. Frazer. op. cit.



NASA

This photo of the Aurora Borealis over Canada was taken by a member of Expedition 30 on the International Space Station

istence hundreds of thousands of years ago or more.

The surface of the planet was radically changed after that discovery. Everywhere sparkled, smoldered, and emerged a hearth of fire, wherever Man lived. On account of this discovery, he survived the cold glacial period.

Man created fire in the midst of living nature, subjecting it to combustion. In this way, by means of fires on the steppes and blazes in the forests, he received the power, relative to the vegetative and animal world surrounding him, which thrust him out of the ranks of other organisms, and presented itself as the prototype of his future existence. Only in our day, in the 19th and 20th Century did Man possess other sources of light and heat—electrical energy. The planet began to glow ever more, and we are presently at the beginning of a time, the significance and future of which for a time remains beyond our ken.

110.

There passed many tens, if not hundreds, of thousands of years until Man possessed other sources of energy, some of which, like steam-power, for instance, appeared to be the direct results of the discovery of fire.

In the course of long millenia, mankind radically transformed his role in the realm of living nature and in a fundamental way transformed living nature on the planet. This began already during the glacial period, when Man began to tame animals, but for many thousands of years this was not so clearly reflected in the biosphere. During the Paleolithic period, only the dog seemed to have a connection to Man.

A fundamental change began in the northern hemisphere beyond the boundaries of the glaciation after the retreat of the last glacier.

It was the discovery of agriculture, creating food independently of the bounty of untilled nature, and the discovery of breeding livestock, which, apart from its significance for Man's sustenance, accelerated the movement of Man.

Today it is difficult to determine precisely the conditions under which agriculture may have arisen. The natural environment surrounding Man at that time, some 20,000 or more years ago, was far different from that we see today in those same locations.[26] It is the result not only of a transformation of Man's cultural activity, as

26. It seems to me that the investigations of N. I. Vavilov regarding the centers where the domestication of animals and plants occurred will compel us to push back considerably further than 20,000 years ago the estimated date for the beginning of agriculture. N. I. Vavilov. *Problema proiskhozhdeniia kulturnykh ractenii*. Moscow-Leningrad, 1926.

was still not long ago believed, but also of a fundamental transformation of the environment of the glacial period in which we are now living. We can clearly see that even in the more recent historical period, the last 5-6,000 years, Man has experienced geological changes in the biosphere. The regions of China, Mesopotamia, Asia Minor, Egypt, possibly even regions of Western Europe beyond the limits of the taiga regions of those times, in terms of its climate, its aquatic regime and its geological morphology, were radically different from today, and it's not possible to explain this simply as a result of the product of the cultural work of Man and its inevitable, albeit unpredictable, consequences. Alongside the cultural labor of Man the spontaneous process of the freezing of the Glacial Maximum proceeded apace, increasing or decreasing in intensity, a process lasting some hundreds of thousands of years—the process of the anthropogenic age.

NASA

Bog land fire, burning since 2012 in Russia.

111.

With the present level of human culture, agriculture is not able to encompass the entire land surface of the Earth. In a recent [1929] estimate, the area of the land devoted to agriculture did not exceed $129.5x10^6$ square kilometers, that is, 25.4% of the surface of the planet.[27] If we consider only the land area of the planet, this becomes 86.3%. We probably have to consider that figure exaggerated, but in general it gives an impression of the tremendous cultural biogeochemical energy by which mankind transformed, in the course of 20,000 years or more, the surface of the planet. We have to keep in mind the fact that the Arctic and Antarctic, the deserts and semi-deserts of north and southern Africa, Central Asia, and the Arabian Peninsula, the North American prairie, a significant portion of Australia, and the high plateau and the high mountains of Tibet and North America are either not suitable for farming or can be farmed only with great difficulty. Taken together, these make up not less than one-fifth of the land area of the globe. One must also note that for Man, even after the discovery of fire at the beginning of his cultural labor, the taiga and the tropical forests represented nearly insurmountable barriers to agriculture. He would have to struggle a long time under these circumstances with the resistance mounted by insects and wild mammals, parasites and weeds, which devoured an enormous, and not infrequently, an overwhelming portion of the product of his labor. Even today in our agricultural endeavors, weeds envelop one-fifth to one-fourth of the harvest—in the beginning, that figure would certainly be a minimal one.[28] Nowadays we have, thanks to the socialist construction of our country, somewhat more accurate figures for calculating the intensity and the potentialities of this form of biogeochemical energy of mankind. We are undergoing an extraordinary expansion of cultivated land. As N. I. Vavilov and his colleagues have shown, only in the last two years (1930-31) the land under cultivation has increased by 18 million hectares, which would have required decades by the old standard.[29] With the aid of planned calculations being utilized by eminent specialists, a general map of our own country has been developed. It embraces an area equal to $2.14x10^7$ square kilo-

27. H. Rew. Agricultural Statistics. *Encyclopaedia Britannica*, 1. London, 1929, p. 388.

28. A. I. Maltsev. "The most recent achievements in studying the weeds in the USSR." *Achievements and perspectives in the area of genetics and selection*. Leningrad, 1929, p. 381.

29. N. I. Vavilov, N.v Kovalev, N.S. Pereverzev. "Plant breeding in connections with the problems of agriculture in the USSR", *Rastenievodstvo*, vol. 1, ch. 1. Leningrad-Moscow, 1933, p. VI.

meters, or 16.6% of the Earth's land surface. Of this, $5.68x10^6$ square kilometers beyond the limits of its northern boundaries are unfit for cultivation. In total, there are around 11.85×10^6 sq.km. unsuitable for agriculture, leaving 9.53×10^6 square kilometers fit for cultivation. Thus the greater part of our country lies beyond the boundaries of modern agriculture or else is deemed unsuitable for it.[30] But this area may be significantly reduced through improvements. The government plan of ameliorating these conditions according to the calculations of L. I. Prasolov[31] will allow an increase of arable land by about 40%. Obviously this is not the end of the possibilities, and there is hardly any doubt that if mankind finds it necessary or desirable, he would be able to develop the energy needed to bring under cultivation the entire land surface, and perhaps even more.[32]

112.

We have still in China an intensive agriculture fully developed for generations, which, in a rather stationary state, existed for more than 4000 years in a country with a huge land area of more than 11 million square miles. Without a doubt, the country's topography changed during that time, but the system of production and agricultural customs were maintained and transformed the mode of life and nature. Only in the most recent period, in this century, does the mass of the population find itself in continual flux with customs that have lasted thousands of years being uprooted. We might speak of Chinese society as a purely agricultural civilization.[33] For countless generations, in the course of more than 4000 years, the population, in general remaining uninterruptedly in the same location, altered the country and in their social existence merged with the surrounding nature. Here probably the greater part of agricultural products are produced, and, yet the population lives under the constant threat of famine.[34] More than three-fourths of the population are farmers. "A large part of China is an ancient nation, settled by farmers with the fields where they worked so close to their limits that large harvests were difficult to keep up. The roots of the Chinese go deep into the earth… The most significant element of 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 nature and given it a human stamp. The Chinese landscape is a biophysical unity, knit together 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 Man and nature as separate phenomena but a single organic whole." [35] And in spite of such unbroken, indefatigable labor of many thousands of years, only a little more than 20 percent of the land area of China is under cultivation,[36] while the remaining area in such a large and naturally rich nation might be improved through government measures, first made possible with our present level of scientific knowledge. A working population existing for thousands of years lives in an area of 3,789,330 square kilometers with an average capacity of 126.3 people on each square kilometer. That is almost the limit of the maximal use of agri-

Vavilov Institute of General Genetics

N. I. Vavilov, plant biologist and geneticist, who was intent upon eliminating famine in Russia. He was targetted for elimination by Trofim Lysenko, and died in Saratov prison in 1943.

30. L.I. Prasolov. "Land reserves for plant breeding in the USSR", Ibid, p. 31.

31. Ibid, p. 37.

32. The possibility of encompassing the oceans in one or another form was expressed a number of times in the scientific utopias even at a time when the physical power of Man was clearly negligible with regard to the powers of the oceans. In the interesting utopia of B. P. Weinberg [*Twenty thousand years from the beginning of the elimination of the oceans*, op. cit.] there is a discussion of that state of Man, which begins, when the reproduction of Man embrace the entire landmass—the state of the neutralization of the oceans. B. P. Weinberg assumes that in the 21st Century that question will be seriously broached. To a certain extent these questions have already become real issues before the mind of Man. The example of Holland in the past on a miniature scale and the idea of Goethe's Faust also on a small scale in the 18th and the beginning of the 19th Century already appear as realistic prototypes of the future. Now it is a matter of establishing a permanent , stationary floating base, existing outside any land area, in the midst of oceans and seas—this also merely the first inkling of what the future may bring.

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.

35. Ibid. p.1.

36. I am using figures provided by G. Cressey as to the total area of tilled land in the provinces and the fields of the small agricultural units and compared it with the total land mass of China. These figures are related to the period between 1928 and 1932. Rhe statistical review by Cressey (p. 395) for agricultural China (including the Hinggan Mountains, the Central Asian steppes and deserts and the areas adjacent to Tibet) gives the number as 379 square kilometers for a population greater than 477 million people—22% of the territory. Thus it is clear that the population is concentrated on a small land area which is utilized to its maximum.

cultural land. It will be, Cressey correctly indicates, from the standpoint of ecological botany, something of a final stage. "Here we have an old stabilized civilization which utilizes the resources of nature 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 is the product of long ages. More human beings have probably lived 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 contour of hill and valley and to the pattern of the fields. The very dust is alive with their heritage." [39] That four thousand-year culture, before it adopted this stabilized form must have experienced a more grim and tragic past, since the former conditions of nature in China were completely different, enveloped by a totally different milieu, with humid forests and marshes; to subdue these and bring them under cultivation—destroying the forests and ridding them of their animal inhabitants—would have taken tens of thousands of years. The latest discoveries reveal that while Europe was experiencing the movements of glacial ice, in China there developed a culture under conditions of a pluvial period.[40] Certainly, the basic system of irrigation, to which agriculture in China owed its existence, had its roots far back in history, 20,000 years ago and more. Until the end of the 20th Century such an ecosystem may have existed in a certain equilibrium. But it could exist only because China was, to a certain degree, isolated, and from time to time the population was decimated by wars, hunger, famine and floods; irrigation work was too weak to cope with such mighty rivers as the Yellow River. Now all of that is rapidly becoming a thing of the past.

In China we see the last example of a unifying civilization lasting millenia. We see at the beginning of the 18th Century when Chinese science stood in high esteem, it experienced a historic shift, and missed the chance of being incorporated at the necessary moment into world science. It was included there only in the second half of the 19th Century.

113.

Agriculture would appear as a geological force, transforming the surrounding nature, only when it occurred together with the raising of livestock, namely, when Man, in addition to the selection and cultivation of plants necessary for his sustenance, also selected and began to breed the animals he needed. Man accomplishes this geological work inadvertently, stimulating a greater reproduction of a certain species of plant and animal organisms, always creating for himself an available supply of food and maintaining a food supply for the animals he needed. In raising livestock he not only obtained a guaranteed food supply, but also increased his muscle-power, allowing him to put more fields under agricultural production at an earlier stage.

In the work of the livestock, he obtained for himself a new form of energy, enabling him to support a larger population, create large settlements, an urban culture, and free himself from the otherwise ever-present threat of famine.

In doing this, he always remained within the bounds of living nature.

During the past centuries, in our age of steam and electricity, the labor-power of livestock and the muscular energy of animals and Man, begin to play a secondary role in the expansion of agriculture. However, even with that, Man does not transcend the bounds of living nature, since the primary source of the electrical and steam energy is that same living nature in the form of living matter or, even more now, past living organisms which have been transformed through geological processes. This energy is obtained from coal and oil. After all, Man has in this manner always made use of solar radiation, which illuminated the Earth for hundreds of millions of years before his appearance, and, which, transmitted through living organisms, were utilized by him either directly, or as preserved in their fossilized form.

In agriculture and livestock are manifest more than anything the cultural biogeochemical energy directed by reason, creating for Man new conditions for his habitat in the biosphere. By these means living nature by and large was radically transformed. For many tens of thousands of years, the inert matter of the biosphere was affected by Man to a degree barely comparable to the present profound transformation in his surrounding living habitat.

As a result of this there has been created a new face of the Earth, that in which we are now living and which began to emerge only in the last millenium. Now change occurs ever more abruptly with each passing decade.

But agriculture alone, even without livestock, radically transforms nature. For in the living nature surrounding it, every vacant area is filled by living organisms, and in or-

37. Cressey, op.cit., pp.1-2

38. Certainly it is not a question of trillions but of a considerably large number of people that have lived on the territory of China, as the presence of the human species and its predecessor, Sinanthropus, in that territory, would have been established in the course of hundreds of thousands of years. The appearance of a new species or race, powerful enough to provide the beginnings of modern Man, may have occurred in one family or at one stage, but could also have occurred over a rather large area. But even in the first case, the number of offspring originating from a single couple must have been much greater than 10 billion over the course of hundreds of thousands of years (even if you introduce) corrections to the general forebears of particular individuals. On this, 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.

Chinese agriculture remained static for many centuries. Here, a representation of a farmer tilling his field with the help of his cattle.

der to introduce new life, Man must make a place, clearing the land from other living organisms. Moreover, he must continually maintain that new living substance established by him from the surrounding pressure of other life, from the animals and plants, which were inserting themselves into the vacant areas cleared by him. He has also to preserve the fruits of his labor from animals and plants, lest they be devoured by mammals, birds, insects, fungi, etc. We see that even at the present stage, he has not been able to definitively accomplish this.

Agriculture together with livestock, continually maintained by human thought and labor, in the end fulfills an enormous geological task. Old life is destroyed, and new life is created—new species of animals and plants, created by the thought and labor of Man, emerge from the old, created under different conditions. But even the world of wild animals and plants that have not been directly affected by Man are inexorably transformed in the new conditions of life created by the biogeochemical energy of Man.

114.

The raising of livestock, apart from agriculture, produces a tremendous change in the surrounding living nature. For it consumes food and condemns to a slow or rapid extinction large mammals, among which Man selects a few species. Man appeared at the end of the Tertiary Period, in the epoch in which large mammals reigned in the biosphere, as Osborne correctly points out. [41]

At the present time, it can be said that these mammals have either practically died out or are rapidly disappearing, and are preserved only in reserves and parks, where their number is relatively stable. Observations in these large reserves show that here practically always a stable dynamic equilibrium is achieved, even independently of Man's will, in which reproduction is regulated by the limited quantity of food for the herbiverous animals and by the quantity of carnivorous animals, for which these serve as food.[42] [43] With an insufficiency of food—and a weakening of their organisms, reproduction is primarily determined by diseases caused by microorganisms. But the total preserved numbers of wild herbiverous mammals can certainly not be compared to the number of domesticated animals—horses, sheep, cattle, pigs, goats, etc., and it is conceivable that their number in the Tertiary Period hardly surpassed the number of domesticated mammals. We don't know that number with any exactitude, but we do have some idea about it. At the present time it exceeds by hundreds of times the number of the human population. According to M. Smith (1910), at the beginning of the century, the number equalled 138 billion. According to H. Rew[44] the number in 1929 for horses, bulls, sheep, cows, and pigs reached 15.7 billion. Not taking into account here species of domesticated animals does not change the order of magnitude of the number. Thus one might say that the expression in billions fluctuated between 16 and 138 billion, significantly exceeding the number of people. The number fluctuates sharply as it is under human control. Thus, according to J. Dufrenoy[45], from 1900 to 1930, the number of livestock diminished

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41. H. Osborn. *The Age of Mammals in Europe, Asia and North America*. N.Y., 1910.

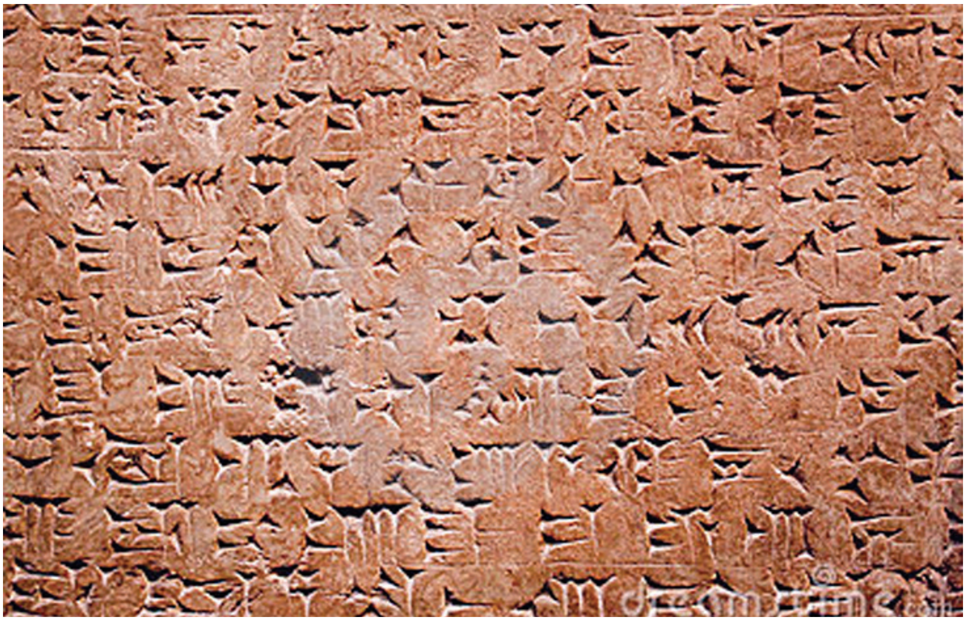
42. See: James Stevenson-Hamilton. *South African Eden: from Sabi Game Reserve to Kruger National Park*. London, 1937.

43. M. Smith. Agricultural Graphics. United States and World Crops and Live Stock, *Bulletin of United States Department of Agriculture*, Washington, 1910. N 10, p. 67.

44. H. Rew. *Encyclopedia Britannica*, v. 1, 1929, p. 388.

45. J. Dufrenoy, *Revue générale des sciences pures et appliquées*. Paris, 1935, N 46, p. 72.

by one fourth, displaced by machinery. As Man came to possess new sources of energy, that number quickly dwindled before our eyes, as, for example, the number of horses, donkeys and mules, owing to the increase of tractors and automobiles.



Cuneiform writing of the ancient Sumerians.

115.

The appearance of livestock and agriculture was established at various times and in various locations within the span of 20,000 to 7,000 years ago, gradually increasing in intensity as we approach our own era. The transition from the nomadic (migratory) hunting and food-gathering phase to our present settled mode of life based primarily on agriculture, occurred at various periods on the boundaries of the uninhabited zones of the temperate latitudes stretching from present-day Morocco to Mongolia. This was possibly the result of climatic changes after the retreat of the last glacial cover and the weakening of the pluvial period[46] of the Pleistocene.

Seven or eight thousand years ago appear the first powerful states based on agricultural and the first large cities. This provided Man with the possibility of unimpeded reproduction with only minor interruptions. Here were established the urban civilizations of the Celtic and the Berber states and their predecessors in Egypt, Crete, Asia Minor, Mesopotamia, northern India, and China. We are entering the age, which power and significance is steadily and rapidly growing over the last three centuries (and from which legends have been preserved and have come down to us, and countless material relics provided, unearthed through archeological excavations).

You might say that within the last five to seven thousand years the continuous creation of the noösphere has proceeded apace, ever increasing in tempo, and that the increase of the cultural biogeochemical energy of mankind is advancing steadily without fundamental regression, albeit with interruptions continually diminishing in duration. There is a growing understanding that this increase has no insurmountable limits, that it is an elemental geological process.

116.

It is appropriate to add here a few additional facts. It is possible to date to somewhat earlier than 4,236 B.C.[47] or earlier the origins of the Egyptian calendar (which is based on many years of observations of Sirius), which served as the basis for the chronology of the entire ancient world right up to the present moment, where it is found spread throughout the entire noösphere. Even before that, somewhere between 5-4,000 B.C., there existed an urban culture in India, Mesopotamia, and Asia Minor, with such a level of technology, which we even as recently as a few years ago did not suspect, encompassing a population numbering perhaps in the millions. At the end of that period, around 3,000 B.C., began a shift toward using animals for transportation, and in the course of the next 1,500 years this rapidly expanded, and included oxen, camels and horses. Around 3,300 B.C., in the temples of Mesopotamia, written script was being used. Records were kept by means of a complicated pictographic script, and around 1,600-1,500 B.C., the Semites in the Near East discovered the use of the alphabet. We can assume that around 2,500 B.C., we already had a clear manifestation of scientific thought, and around 2,000 B.C. in Mesopotamia, we had the discovery of the decimal system. At this time old records, written some centuries earlier, were copied and preserved in libraries. Between the 15th and 16th centuries B.C., we note wide-ranging exchanges in

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46. N. Nelson recently provided a concise review of this on a global scale. See: N. Nelson. Prehistoric Archeology; Past, Present and Future, *Science*, 1937, v. 85, N 2195, p. 87.

47. It may be that the choice is between these two dates—4236 B.C. and 2776 B.C. From what we now know, taking into consideration the growth of studies in history and archaeology, it appears that the first figure is the correct one. See: Naum Idelson, *The History of the Calendar*, Leningrad, 1925.

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Vernadsky with the workers of the Biogeochemical Laboratory which he established in 1928

ples, the unity of the noösphere, became the order of the day. It is not possible to reverse this process, but it bears the character of a ruthless struggle, which, however, is grounded on the deep roots of an elemental geological process, which may last two or three generations, or more (although it is hardly probable judging from the tempo of evolution in the last thousand years). In that transitional stage, amidst the intense struggles which we are now undergoing, it would as well seem less likely that there will be any protracted interruptions in the ongoing process of the transition from the biosphere to the noösphere.

The scientific grasp of the biosphere which we now observe is an expression of that transition.

Its non-fortuitous nature and its connection to the structure of the planet—its outer envelope[48]—we must later subject to a possibly deeper thoughtful logical analysis, in considering an understanding of biogeochemistry.

All the above exposition is the result of precise scientific observation, and insofar as this was faithfully done, it ought to be considered a scientific generalization.

It is a scientific description of a natural phenomenon, without the assumption of any hypotheses, theories or extrapolations.

the cultural world of scholars, philosophers, and physicians of that period. Around 2,000 B.C. or earlier we have the discovery of bronze, probably simultaneously in several places, and around 1400 B.C., the discovery of iron, which in the course of a few centuries came into general use.

With these momentous achievements we have now arrived at the first century B.C., in which scientific, philosophical, artistic and religious creativity achieved an enormous development and laid the first foundations for our civilization.

In the course of the last 500 years, from the 15th to the 20th Century, Man's powerful influence over his surrounding nature and his comprehension of it, ceaselessly advanced, becoming ever stronger. In this period the entire surface of the planet was embraced by a single culture: the discovery of printing, knowledge of all earlier inaccessible areas of the globe, the mastery of new forms of energy—steam, electricity, radioactivity, the mastery of all the chemical elements and their utilization for the needs of Man, the creation of the telegraph and the radio, the penetration into the Earth to the depth of a kilometer by boring, and the ascension of men in aerial machines to a height of more than 20 kilometers from the surface of the Earth, and of mechanical devices, to a height of more than 40 kilometers. Profound social changes, giving support to the broad masses, advanced their interests into the first rank, and the question of eliminating malnutrition and famine, became a realistic option that can no longer be ignored.

The question of a planned unified activity for the mastery of nature and a just distribution of wealth associated with a consciousness of the unity and equality of all peo-

117.

Observing thus the developed scientific disciplines, we see that there exist sciences of different types: in the first category, we have those whose objects, and consequently whose laws, encompass all of reality, such as our planet and its biosphere, as well as the cosmic expanses—that is, sciences whose objects correspond to the fundamental, universal phenomena of reality. The second category is related to phenomena which are characteristic of our Earth.

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48. Actually this is possibly a second envelope of the Earth's crust—the stratosphere, encompassing life (mainly through Man—the noösphere), and it ought to be included in the biosphere. (See:V.I. Vernadsky, "On the limits of the biosphere," *Izvestiia* AN, geological series, 1936, No. 1, p. 3-24). We should think of the upper layers (60-1000 km.) not as part of the Earth's crust, but as analogous to the Earth's crust in the division of the planet, that is, concentric with the planet. The Earth's crust will be the second sphere, and the biosphere is its outer envelope. This, of course, will soon become clear.

In this latter category, we might theoretically admit two classes of scientific objects to be investigated: general planetary phenomena, and individual, purely terrestrial, phenomena.

At present, however, it is not always possible to differentiate reliably and with a sufficient degree of certainty between these two cases. This remains a task for the future.

Here it concerns all the sciences of the biosphere, with the sciences of the humanities, with the Earth sciences—botany, zoology, geology, mineralogy—in all their scope.

Considering such a condition of our knowledge, we can distinguish an expression of the influence on the structure of the noösphere of two areas of human thought: the sciences common to all reality (physics, astronomy, chemistry, mathematics), and sciences related to the Earth (biological, geological, and humanistic sciences).

118.

Logic occupies a special position, in the most intimate manner connected to human thought, embracing equally all of the sciences: both the humanities, on the one hand, and the mathematical sciences, on the other.

Actually it should be included in the realm of planetary phenomena, because only by means of it is Man able to understand and scientifically grasp all reality—the scientifically structured Cosmos.

Scientific thought is both individual and social. It is inseparable from Man. Not even in his deepest levels of abstraction can an individual transcend the realm of his existence. Science has a real existence, and like Man himself, is most closely and inextricably bound to the noösphere. The individual is obliterated—"decomposed"—when he goes beyond the logical grasp of his intellect.

But the mechanism of the understanding, tightly linked to speech and concepts—the logical structure of which is complex, as we shall see (observe the digression on logic at the end of the book)—does not encompass the totality of Man's knowledge of reality.

We see and we know, but we know in an everyday, not in a scientific way, that creative scientific thought transcends the bounds of logic (including logic and dialectics in its various forms). The individual, in his scientific accomplishments, bases himself on phenomena, which are not encompassed by logic (however broadly we understand that term). Intuition, inspiration, the basis of the greatest scientific discoveries, proceeding and operating further in a strictly logical manner—is not brought forth by either scientific or logical thought, nor is it connected to words or concepts in its genesis.

With regard to this fundamental area in the history of scientific thought, we are entering into a realm still not fully grasped by science. But not only can we not take it into consideration, rather we must increase our scientific focus on it. At present this area of philosophical speculation is somewhat clarified, but in general still finds itself in a chaotic state.

This area has been investigated with greater interest and depth in Hindu philosophy, both ancient and modern. Here we have attempts to delve into this realm, barely touched by science.[49] How far it will conduct human thought, and give it a direction—of this we have no definite knowledge.

We only see that a large realm of phenomena, which possess a rigorously lawful, most intrinsic, relationship to the social order, and ultimately, to the biosphere—even more to the noösphere—namely, the world of artistic creation, is not reducible in any meaningful way in any of its parts, for example, in music or architecture, to verbal representation, and yet it exerts a great influence on the scientific analysis of reality. The mastery of this cognitive apparatus, little reflected by logic, is a task for the future.

119.

Biogeochemistry in its greater part, the objects of which are atoms and their chemical properties, ought to be ascribed to the category of the general sciences. However, as a sub-division of geochemistry, that is, the geochemistry of the biosphere, it appears as a science of the second type, that is, associated with the small, more circumscribed, natural bodies of the universe—with the Earth, or, in the more general case, with the planet.

But, in studying the manifestation of atoms and their chemical reactions on our planet, biogeochemistry fundamentally transcends the limits of the planet, and basing itself, like chemistry and geochemistry, on the atom, it is thereby involved with more potent problems than those simply characteristic of planet Earth—namely, with the science of the atom and with atomic physics—with the very foundations of our understanding of reality in its cosmic dimension.

This is less clear with regard to life which is studied by it in its atomic aspect.

Do the problems of biogeochemistry also here transcend the boundaries of the planet? And how far out do they emanate?

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49. To avoid any misunderstandings I should explain that I have here in mind not some theosophical quest, which would be far removed from contemporary science, as well as from contemporary philosophy. Both in the new and in the ancient Indian thought there exist philosophical currents, by no means contradicting our contemporary science (actually less so than do the philosophical systems in the West), as, for example, some systems associated with Advaita-Vedanta, or even the religious-philosophical investigations, as far as I know them, of the prominent religious thinker, Aurobindo Ghoshi.