BETWEEN 'BIOSPHERE' AND 'GAIA': EARTH AS A LIVING ORGANISM IN SOVIET GEO-ECOLOGY[1]

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ABSTRACT: This paper focuses on some aspects of Russian naturalism that were crucial to the development of a systemic and cybernetic approach to earth sciences in the Soviet Union. The author seeks to connect Soviet perspectives to the wider context of global ecology by examining three main topics: the intersection between environmentalism and research addressing holistic ecology; the attempt at a unification of biology and geology, encouraged by V. I. Vernadskij's "pre-Gaian" concept of Biosphere as a living organism; and, the emergence of Cybernetics which accompanied the rise of a systems ecology with its implicit global understanding of environmental problems. By discussing genuine differences in styles of thinking among Russian scientists compared to Western scientists, the article is an attempt to argue that Russian science is better situated to develop an appreciation of holistic phenomena and is more conducive to interdisciplinary work than Western science, and consequently has been the source of some of the most original ideas in ecology.

KEYWORDS: Russian explorations; Earth System; Geology; Gaia; Biosphere; Cybernetics; Environment; Co-evolution.

RUSSIAN NATURALISM AND THE SYSTEMIC APPROACH IN THE STUDY OF NATURE. A CROSS-DISCIPLINARY FIELD

The interdisciplinary framework used by Russian naturalists dating back to the Age of Explorations partially informed the evolutionary systems approach in natural sciences during the 20th Century. Naturalism in Russia had a powerful and glorious tradition, and "one of the strongest areas of Russian science from the earliest days to the present

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has been that of geographical explorations." [2] These were initiated during the reign of Peter the Great (1689-1725) and continued until approximately the first half of 19th Century (Graham, 1993: 24). Thanks to the presence of vast uncontaminated lands, the expeditions were an ideal opportunity to gather a rich variety of *flora* and *fauna,* to study the morphology of different soils and observe the interactive relationship between organisms and their environment. New branches of science, such as systematics and taxonomy, arose during the Age of Discovery, attracting naturalists from all over the Europe to the Russian Academy of Science.[3] Geography, cartography and oceanography also received a boost in this period as disciplines necessary for orientation across the huge country and to locate conquerable areas. Expeditions had, in fact, a geopolitical, economic and military importance, aiming to exploit natural sources, while competing with European monarchies to achieve supremacy in the maritime trade on the Pacific coast of Siberia. At the same time, "the scientific output of these expeditions was enormous" (Graham, 1993: 25). The myriad of brilliant scientific results, the amount of volumes published between 1700 and 1800, and the collections of specimens conserved at the Academy of Sciences of St. Petersburg, made this age one of the most successful for the dissemination of natural sciences.[4] Judging by the rapid growth of the number of scientific journals, papers and books, two research fields in particular became very popular at the end of the Age of Discovery: geology and biology.[5] Furthermore "the most important result for Russia, was the creation of its impressive tradition in the earth and life sciences" that had its

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[2] As the Soviet geologist Alexander Fersman claimed "our geography is the work of tens of thousands of people participating in expeditions which have traversed our country in different directions and recorded remarkable discoveries" (1944: 38).

[3] "The eighteenth-century expeditions involved hundreds of men organized in whole constellations of activities. The best known was the first Kamchatka expeditions (1725-9), under the leadership of the Dane Vitus Bering; the second Kamchatka, or Great Northern Expeditions (1734-43) directed by the Admiralty; and the academy expeditions of 1768-74 guided primarily by Peter Simon Pallas, the great German naturalist who became a member of St. Petersburg Academy and spent many years in Russia. The great Northern Expedition included many well qualified scientists, including the astronomer Louis Delisle, de la Croyere, the naturalists Johann Gmelin and George Steller, the historian Gerhard Müller, and the young Russian naturalist Krasheninnikov" (Graham, 1993: 25).

[4] The basic contributions to these expeditions are contained in volumes most of which attracted the immediate attention of scholars everywhere. This material enriched every branch of natural science (Vucinich, 1963).

[5] As Grigoriev and Graham indicated, geology developed such a strong tradition in Russia that later on, during the 20th century, geological branch comprised more than 10,000 specialists with higher education in 1947, while by the early 1950s geologists accounted for about one half of the total number of geologists in the entire world (see Bolotova, 2004). However, "other distinguished eighteenth-century researches, both foreign and Russian, in the related fields of geology, biology included J. Gmelin, G. Steller, S. P. Krasheninnikov, M. V. Lomonosov, V. M. Severgin, A. I. Chirikov, I. I. Lepekhin, I. A. Güldenstädt and N. Ia. Ozeretskovskij" (Graham, 1993: 31).

peak between the end of the 19th and the beginning of the 20th century (Graham, 1993: 25). Such a legacy produced a particular attitude among Russian naturalists who adopted an uncommon method to investigate the history of earth and the history of life on earth, treating it as an integrated subject.

According to Vyacheslav and Balandin (2004), the idea of merging geo-evolution and bio-evolution in a unified research pattern came at the end of a long period dominated by a specific view of the planet earth and, especially, of its place within the cosmos. This interpretation of earth, conceived as a mechanistic body subjected to a few mathematical and physical lows, no longer satisfied scientists' new achievements in the field of natural sciences. During the first half of the 20th Century geography and geology which had been descriptive sciences of the physics of earth, exhausted their specific object of investigation as all the major territories of the planet were described in those terms. To discover new areas to investigate became fairly difficult insomuch as it became clear that geography and geology could no longer be only based upon geophysical studies (Vyacheslav *et al.*, 2004). They had to extend the focus to their study to chemical reactions that occur on earth's surface. As a result, the new discipline known as geo-chemistry, whose founders were the mineralogist Vladimir I. Vernadsky (1863-1945) and the geologist Alexander E. Fersman (1883-1945) were founded. A few years later, the focus of geology shifted to the whole biosphere – the environment of life.

Vernadskij characterised these two different interpretations of the earth tied to different images of the cosmos, in the preface of his book *Zhivoe veshestvo* (*Living Matter*, 1978) "The two images of the cosmos". Firstly, there is the physical and mechanical representation in terms of ether, energy, electrons, lines and particles that, according to Vernadskij, is completely foreign to us, having nothing to do with living beings. On the other side, there is the conception summarised by the author:

> In addition to this physical image of the cosmos there is the naturalistic representation of it which is not split into geometric shapes. On the contrary, it is more complex, realistic and familiar to our thinking. This view is closely related, rather than to the whole cosmos as the previous one, to a part of it, namely to our planet, whose representation may be understood by any naturalists who have studied the scientific descriptions of earth and its surroundings. In this representation there is an element always missed within the physical conception of the cosmos: the living matter. Such representation of nature is not less scientific than the first based on physico-mathematical theories. Furthermore, it provides different aspects of the cosmos, often left out of the abstract theories (Vernadskij, 1978: 15).

From childhood, Vernadskij had spent all his spare time studying nature. He took long walks across virgin Ukrainian lands with the astronomer Evgraf M. Korolenko who taught him to look at the earth as a living organism (Grinevald, 1993). His main mentor was Vasilij V. Dokuchaev (1846-1903), a leading crystallographer and founding father of pedology, the science of soil (Graham, 1993; Vucinich, 1963). Dokuchaev illuminated the role of life in the evolution and stability of the earth's crust that, in his eyes, was a product of living organisms. He became famous for the theory according to which the soil needs to be investigated as a complex system constituted by numerous parts interacting with each other. He suggested investigating each aspect of nature, never isolating them and never forgetting that their existence depends on all external circumstances. Thanks to Dokuchaev's teachings, Vernadskij realised that "soil is a geobiological formation with an evolutionary history formed not only by the bedrock but also by plant and animals" (Graham, 1993: 230). And a few years later he became convinced that the earth's crust is modified by the interaction of living and inorganic matter – they exist and develop only in a close connection, as a *multiplex* evolving unity. Vernadskij noted that specific features of the Russian soil, in particular its homogeneous morphology, allowed us to vividly observe the influence of the climate on the formation of vegetation and mold. Crossing different landscapes one could find a rich variety of physical, geological and also biological features according to the influence of different meteorological conditions upon *flora* and *fauna*. He concluded that soil is a *bioinert* body as it is neither completely organic nor completely inorganic, referring to the interconnectedness of inorganic substances, such as minerals, and biological substances, such as microorganisms that are continually crossed by chemical compounds, which for the most part are constituted by them. This characteristic of the soil led Vernadskij to use a cross-disciplinary method and adopt a bio-geo-chemical research pattern to better appreciate the complexity of this relationship.

According to Vyacheslav and Balandin (2009), new achievements and technological progress made possible the discovery of new lands and seas as well the development of other fields, such as the aviation. The launch of the Sputnik in 1957 opened up again the bio-geophysical sciences as a way to comprehend the earth from a cosmic perspective.[6] Not surprisingly the interest in space research, in geology and the study of biosphere often advanced at the same time. Geologists became almost cult

[6] According to Vyacheslav, through the Sputnik it was possible to discover important and useful mineral deposits that from the earth, because of its complex morphology, would have been difficult to identify. One of the pioneers on this topic of research that came to be known as cosmogeology, the Soviet geochemist Kirill P. Florensky experienced in planetology and earth science, was a student of Vernadskij and son of the philosopher and mathematician Pavel Alexandrovich. Florensky noticed that the craters on some planets might reveal, or at least help to guess, geological stages of earth (Vyacheslav *et.al*, 2004).

figures in Soviet society, standing on a par with cosmonauts and pilots (Bolotova, 2004). A good instance is Alexander L. Chizhevskij (1897-1964) with a background in the philosophy of space. He pioneered the national aircraft technology working with Konstantin E. Tsiol'kovskij (1857-1935), the philosophical founder of Cosmonautics. Although his commitments were mainly related to space rocketry and technology studies (he was not a geologist by training), Chizhevskij is famous also for his theorisation of space ecology (Yagodinskij, 2005). In his suggestive view, life should not be considered a product of the earth's surface, but rather as a result of the sun's radiation.[7]

In the second half of the 20th Century, geophysics was about to be transformed in a new research field in the Soviet Union, grounded in a holistic approach in which the role of living organisms was the most significant for the evolution of earth and vice versa. But the interest in systems ecology lay not only on theoretical grounds: scientists who endorsed this approach in earth sciences often took an active role in the defence of the environment, despite Stalin's opposition to such sensible policies.

THE ENVIRONMENTAL AND ECOLOGICAL BATTLE FOR ZAPOVEDNIKI

The concern over environmental problems was manifest in the concrete activities of a group of intellectuals. It started before Khrushchev's time but scientific groups usually opposed industrial projects on environmental grounds, especially after the 50s.[8]

The Independent Social Movements for the Protection of Nature, for example, after 1924 was a real force in Russia and the Soviet Union, even with all the attempts which were made to cripple its environmental activities and prevent the international circulation of knowledge during the Cold War. The history of this has been treated in detail by Douglas Weiner, especially in his two books: *Models of Nature* (1988), and *A Little Corner of Freedom* (1999). As he showed, the movement – that was institutionalised in scientific societies of botanists, biologists, geologists and geographers – pursued the

[7] As he wrote, "We usually used to refer to rough, narrow, anti-philosophical conceptions of life as a mere result of random plays exercised by land forces. This is surely incorrect. Life, as we see it, in a broader sense, is a cosmic phenomenon rather than a terrestrial one. Life has been created by the activity of the cosmos upon the inert matter of the earth. Life lives the dynamics of these forces and every beat of this organic impulse is correlated to the cosmic heartbeat, in a great whole made of clouds, stars, sun and planets" (Chizhevskij, 1976: 22).

[8] As Medvedev observed, it was the geneticists who set the fire among Khrushchev, nuclear physicists and aerospace scientists, bringing into focus environmental problems in the 50s. The best-known case in which Khrushchev was opposed by the academy was the project for the cellulose pulp mill on Lake Baikal that he decided to carry out despite strong scientific objections based on the damage that might be caused to the environment and to the pollution of the extremely pure water of this special lake (See Medvedev, 1979).

preservation of scientific nature reserves, in Russian *Zapovedniki*, conceived as absolutely inviolable territories.

The society had been criticised by the Communist Party since the '50s because it did not provide any support for the great Plan for the Transformation of Nature[9]. Conservation, which represented a threat to Stalin's projects for the collectivisation and industrialisation of the country, was late also mocked by Khrushchev (Haigh, 2003). This was not a surprise considering that immediately after Stalin's death the scientists belonging to societies organised protests in order to demand the restoration of nature reserves eliminated earlier by Stalin, and even struggled to expand the network (Weiner, 1999). Environmental activists were nevertheless tolerated because "the regime dismissed environmentalists as cranks, rather than real dissidents" (Haigh, 2003: 556). As was revealed by Weiner's research, these movements indeed survived Stalin and all his successors and were never entirely ignored by the Government. Even better, VOOP[10] was the only institution that escaped elimination, reducing the pervasive effect of the Party control, through ecologists's refusal to endorse economic policies.

As Weiner showed, to establish contacts among Nature Protection Organisations was dangerous, nevertheless these societies made attempts to keep in touch each other. They prided themselves on their tradition of keeping foreign contacts and frequently asked for authorisation to travel to international conferences on Conservation. In turn, they often received photographs, package containing journals and letters expressing the desire to receive information on wildlife in the Soviet Union, or asking for Soviet participation in the organisation of international societies. These requests, as documented by Weiner, came from the Austrian and Polish movements, among others. Refusal of permission from the Party blocked attempts to establish a bridge with the Western world, but the VOOP tried to turn the Cold War to their advantage. Since all the contacts among activists in a divided world had to be handled through an agency charged with supervising contacts with foreign countries, VOOP leaders pursued a strategy of keeping international links open while remaining aside from Cold War campaigns to demonize the West. As a matter of fact, the Nature protection

[9] The stress on the transformation of Russian lands that Stalin's Great Plan and other projects aimed to realize was reflected even in literature. During the Stalinist era every field of study was dominated by the metaphor of the "struggle with nature" (Shtil'mark 1992, Bolotova, 2004). The colonization of wild areas by the new Soviet man was described as a glorious mission. It is not simply a case that as a result of the disruptive Soviet policy, as Bolotova wrote: "Numerous territories in today's Russia are considered 'environmental disaster areas' – another consequence of the hegemonic discourse of conquering nature" (2004: 115).

[10] "Vserossiskoe obshestvo okhrany prirody" (The all Russian Societies for the Protection of Nature).

movement aimed at transcending the struggle between the blocs; the international world of science had to be free from political interference. One the most relevant aspects of the movement, according to Weiner, was indeed the civic involvement and the creation of a scientific public opinion independent of the party seeking to maintain an internal democracy.

It is noteworthy that the commitment to nature protection, where nature was conceived as a network of exchanging processes of matter and energy occurring on the earth's surface, was summarised by the idea of Zapovednik – namely, a Biosphere sanctuary. As Weiner wrote, this term was first developed by Dokuchaev, meaning by it a land or a marine territory forever wild, completely excluding economic use, protected by the state (Weiner, 1999). Grounded in this view, ecologists began to conduct their study in these protected territories "which were off-limits to any uses except for scientific research on ecological/evolutionary problems" (Weiner, 1999: 114). The ecological paradigms to which they referred in their studies were basically two: the *Biocenology* and the *Biogeocenology*. The first one invoked by Vladimir V. Stanchinskij (1887-1947) was an energetics and thermodynamic paradigm based on the idea that the quantity of living matter depends on the amount of solar energy transformed by ecological communities at different trophic level of the food chain (Mirovitskaya, Ascher, 2002). Vernadskij preferred to use this term instead of Biosphere although he considered them mostly as synonymous. The second epistemological pattern was formulated by geobotanist Vladimir N. Sukachev (1880-1967) who was Vernadskij's friend and the President of Moscow Naturalist Society from 1955 to 1967. "Sukachev strongly opposed to Lysenko's forest planting methods in Russia's south and southeast which constituted an important element in Stalin's Plan for the Transformation of Nature" (Weiner, 1999: 89).[11] According to the theory of *Biogeocenology,* the earth surface has been shaped over time by the bio-geo-chemical correlation of all the processes occurring on it. But rather then simply a "correlation" of earth components, Biogeocenology introduced the process of co-evolution, the result of which is the environmental synergy of all the elements, biotic and abiotic, of the ecosystem to a stage not foreseeable by the mere sum of those elements at a previous state. In other words this is what Odum would call later the Emergent Property Principle in regard to a functioning ecological whole not reducible to the sum of its parts (2005).

[11] Lysenko's triumph in the frame of 1948 Academy session was a profitable occasion for him to attack the movements for Nature protection. Several years before, in 1930, Isack I. Prezent, Lysenko's mentor, moved from ecology, the first field he ruined, to Soviet biology. He had surprised people during a Stanchinskij talk he emerged as a critic of biocenology, expressing doubts about ecology's right to call itself a science (Weiner, 1989).

One aspect that could be inferred by the wide picture described by Weiner, is that policy on Nature reserves in the Soviet Union shows that the interest in ecological research and the commitments over environmentalism in some cases go together. Species and landscapes preservation and a multidisciplinary scientific research in holistic ecology were necessary for both tasks. Russian Zapovedniky were seen as self-organizing systems in which ecological communities lived in a homeostatic equilibrium. The mechanism of feedback – that exists in those cases in which each part of the system affects the other and each part acts in different ways according to the stimulus received – would play the leading role in identifying the extent of this equilibrium (Odum, 1983). In Russia, nature conservation policy and related scientific research that investigated the self-regulating structure of biocenosis as a whole system was an established approach since the first decades of the Twentieth Century. Here the systemic view of earth did not need to appeal to cybernetics to develop. In the United States, conversely, the notion of "homeostasis" as well "feedback" could be applied to the Biosphere to better understand environmental issues only once Cybernetics and information technology were officially born in the 50s.

BIOSPHERE AND GAIA. UNITED IDEOLOGICAL FRAMEWORKS AND DIVIDED CONCEPTUAL DEVELOPMENTS

Cybernetics revolutionised not only the field of information technology, but also the way in which ecologists saw the earth itself. Its founder, the mathematician Norbert Wiener, brought about a revolution, announcing his new science in 1948 after having worked on the problem of destroying enemy airplanes (Galison, 1994). Indeed Wiener came to the conclusion that through his work on the construction of the Antiaircraft Predictor designed to intercept the position of the enemy's plane by anticipating the pilot's zigzagging flight, he had founded a new paradigm (Galison, 1994). Seeking to expand the epistemological validity of his researches, he "postulated that control via feedback and communication via information exchange constituted universal mechanisms of purposeful behaviour for both living organisms and self-regulating machines" (Gerovitch, 2001: 546). His book, *Cybernetics or Control and Communication in the Animal and the Machine* published in 1948, was the manifesto of this new revolution.[12] Cybernetics provided new principles to investigate complex systems from the

[12] When the Russian scientist Alexander Bogdanov, nowadays recognized as one of the pioneers of cybernetics and systems thinking, wrote his *Tektology, General Science of Organization* (1913-1924), times were not ready to accept his explosive insights. Norbert Wiener, the father of cybernetics, did not mention Bogdanov's work although most likely he knew it since Bogdanov's *Tektology* had been translated into German and published in Germany in 1928 where Wiener often lived by that time (See Biggart *et al*, 1998 and Pushkin *et al.*, 1994).

viewpoint of the relationship between *input* – the information coming from the environment into a system – and *output* – the information released by a system into the environment, whereas systems could be both, artificial and natural. However, while in the United States the earth began to be interpreted as a whole system only after the convergence with technological models exploited by cybernetics had been established – which is what Bryant, to elucidate the connection between ecology and technology in the US postwar period (2006), called a "techno-ecological system" – in the Soviet Union the systemic idea of earth preexisted to the appearance of cybernetics. Nevertheless, Cybernetics in the Soviet Union was immediately embraced as a discipline of crucial importance in relation to ecology and environmental studies in which the new concept of the flow of information was by now a key research topic (Graham, 1987). Cybernetics achieved widespread application: as Gerovitch pointed out, "Soviet cybernetics transcended the domain of engineering and fashioned itself as a science – a systematic study of the laws of nature" (2002: 177). As a result, it "enjoyed more prestige in the Soviet Union in the 1960's than in any other country in the world" (1972: 324).

During the Cold War, technology's dependence on cybernetic patterns had an important effect on the emergence of global environmentalism. In the Soviet Union in 1970 this concern led to the construction of a computing system that simulated, with the help of several devices, all the functions of the biosphere as an integrated system. The prototype placed at the Computational Centre of the Soviet Academy of Sciences reproduced in part consequences that would be caused by the war involving nuclear weapons (Moiseev, 1998). After World War II processes of "mutual civilisation" – a term by which Moiseev means the creation in the last decades of the twentieth century of a contemporary paradigm of global awareness – and the constitution of transnational corporations concerned with the global economy, made clear why the health of our planet should come before all else. On this view a multidisciplinary study of the earth was an essential task because the world in which we live requires a common effort coordinating analogous practices (Moiseev, 1998). The global understanding of the whole earth was encapsulated in popular metaphors like "Spaceship Earth" or "Mother Earth" that, in some ways, reveals the connections between Cold War technologies, space travel, cybernetics, and the birth of the first global environmentalist movement. These concepts invited people to look beyond the struggle of the Cold War and imagine a common future for all living things on the planet (Deese, 2009). In the geo-ecology field, *Gaia* was a metaphor that received a particular attention, despite the fact that its founder, the British chemist and environmentalist James Lovelock was considered a maverick, and did not gain immediately the favour of the scientific community. His theory, The *Gaia hypothesis,* has been at the same time influential and controversial. It described the planet as a super self-regulating organism in which biosphere, atmosphere, oceans and soil interact, self-organizing their functions in order to maintain stability of the whole (Lovelock, 1979). Not surprisingly, Lovelock's theory has been linked to Vernadskj's several times by historians of ecology (Grinevald, 1993; Margalef, 1997; Odum, 1983). The Russian geochemist is in turn widely considered as the most important of the "pre-Gaian" thinkers (Gribbin, 2009). *Gaia* was a living planet in the same way as Vernadskij's *Biosphere*. However, Lovelock did not recognise the similarity between his theory and that formulated by Vernadskij. He thought he was the first to introduce new cybernetic methods in the field of ecology and declared that his use of "feedback" made the difference between his theory and the one elaborated by Vernadskij. The British scientist did not cite Vernadskij's biogeochemistry in his book *Gaia: New Look at Life on Earth* (1979), although there were many occasions in which Lovelock could have learned of the Russian scientist's work. As much as he praised Vernadskij's insights many years later, Lovelock said "I defy you to find, anywhere in Vernadskij's writings, a clear statement of the importance of feedbacks involving life in maintaining conditions suitable for life on Earth" – namely the key concept of Gaia Theory (Gribbin, 2009: 1004). Lovelock was eager to protect his claim to the originality of his ideas, and it is out of this discussion the two perspectives are held to be distinct in many ways.[13] However, Vernadskij's theory of the biosphere anticipated in several aspects Lovelock's attempt to invoke feedback in relation to the possibility that organisms regulate the external environment (for instance, the composition of the atmosphere) for their own benefit. Vernadskij recognised the value of self-regulating processes involving Life's tendency toward its own expansion. Moreover, this issue characterised also Stanchinskij's studies on energy transformation in the biocenosis, accompanying the establishment of ecological research in protected *zapovedniki*. According to Vernadskij, Life on Earth depends on solar energy and the biosphere is that region in which solar energy is converted by living components in order to feed the planet so that life is able to evolve and expand itself. Life is a planetary force that has transformed its environment on earth to a considerable extent (Aksenov, 2012). Vernadskij not only was aware of the role Life played in creating an environment suitable for its own evolution, but, even better his biogeochemical paradigm had the

[13] As J. and M. Gribbin highlighted in their book (2009), an important difference between Vernadskij and Lovelock is that, according to the Russian scientist, living organisms have to be studied empirically as a particular body that cannot be understood in terms of known physic-chemical systems. They cannot be reduced to nothing but known physics-chemical systems. Lovelock, conversely, believes that earth system can be understood in terms of known physical-chemical systems and that the interactions between the living and non-living components maintains conditions beneficial to life.

merit to describe *co-evolutionary* processes involving Life and its environment as an *emergent* phenomenon, instead of as an interaction between two separated entities. In this way, Vernadskij's theory surpassed the implicit dualism connected to the notions of *input* and *output* that featured American cybernetics so prominently. The problem of the origin of Life was for Vernadskij the problem of the origin of the Biosphere.

The breakthrough brought by Vernadskij's theory had such an impact for the development of the study of biosphere that even George E. Hutchinson, the father of modern systems ecology, realised that Vernadskij had established a speculative tradition which has proved to have immense stimulatory power (Bailes, 1981). Not surprisingly, Hutchinson was one of the main sources of Lovelock's Hypothesis and a great admirer of Russian geochemist, whose articles he managed to obtain through Vernadskij's son at Yale University where they both worked. Vernadskij first formulated questions that were crucial for understanding the earth's evolution and the entanglement between living matter and the inert matter of biosphere. In Vernadskij's time the interest in bio-geo-chemistry and the branch of study known as energetics were receiving notable attention also by American mathematician Alfred Lotka (1880-1949). Lotka was working on his *Elements of Physical Biology* (1925), a book published in the USA that appeared just one year before Vernadskij wrote the *Biosphere*. Lotka was not only one of Vernadskij's contemporary born in the current Ukraine where Vernadskij set up his laboratory in Kiev, but also the foremost source for the Gaia theory, as Lovelock acknowledged. His volume also described the transformation of energy and its role in shaping the evolution of earth, bringing attention to systems ecology. Although Gribbin wrote that they knew nothing of each other's work at that time, Lotka cited Vernadskij in the first edition of his book, suggesting in a note to read his work in order to know more about the "distribution of the chemical elements in organic nature", apologising for having received his text too late to provide the readers with a deeper description (Lotka, 1925: 203). Vernadskij and Lotka had a similar view: organisms and environments constituted one system – a complex living organism seen as a whole. It is not the organisms or the species that evolve, but the entire system in which its parts are inseparable. Furthermore, Lovelock praised Lotka because he had predicted the environmental effects of industrial achievements based on the exploitation of fossil fuel (Gribbin, 2009). Also in this case, the awareness of the influence that human's activities have on earth represented a further meeting of minds between the American biophysicist and the Russian geo-chemist. Vernadskij, in fact, introduced the term *Noosphere* to denote the evolutionary stage of Biosphere in which the earth's crust changes its "face" because of the increasing impact of humanity's science and technology (Vernadskij, 1944). Not surprisingly, since 1960, with the growth of environmentalist movements, Soviet interest in Vernadskij's ideas received a significant revival (Bailes, 1990). As Bailes wrote, citing A. I. Perelman:

> Vernadskij saw what a huge geological force humanity had become, how quickly it was transforming the planet, how it was changing in a basic way the migration of chemical elements. He emphasised that man is artificially creating processes which never before existed in the biosphere and are alien to it. He issued a call for the study of these phenomena from the view point of geochemistry, to analyze them, to study the long-range consequences of economic activities […]. The ideas of the founder of geochemistry will continue to illuminate the path of research of these important problems for years head, (Bailes, 1990: 182).

An interesting epistemological aspect emerges from the fact that Lotka, actually, did not become famous in the United States for his theorisation of the "whole earth system". He was mostly recognised as one of the pioneers of population dynamics and the study of the relationship between predators and prey (Gribbin, 2009). This reveals a shortcoming and systematic bias in Western science. The study of the biosphere was doomed to marginalization by a growing specialisation connected with the epistemological bias towards reductionism against holism. Lovelock's Gaia hypothesis, when it was first put forward, was met with hostility from mainstream scientists, and it was a long time before the significance of Lotka's theories was properly recognised.

Russian approaches to ecology are distinctive, in large part, because of their distinctive broader intellectual and naturalistic traditions. It is the holistic and ecological underpinning of these approaches – related to their particular approach to the study of land, climate and nature which has developed since the Age of Discovery – that provides the basis for the systemic and interdisciplinary attitude that distinguishes Russian 'whole earth' science. Russians did not anticipate all aspects of the Gaia hypothesis, but they were in a good position to embrace it and further develop it.

By giving a place to holistic thinkers who crossed disciplinary boundaries fostering a systemic approach decades before systems ecology developed in Europe and the United States, Russian science opened new vistas to which Western science tends to be blind.

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