Appendix

Vernadsky and the Future of Biophysics

by Jonathan Tennenbaum

We here publish an English translation of a little-known article by the great Russian-Ukrainian naturalist and founder of the science of the biosphere, Vladimir Ivanovich Vernadsky (1863-1945), which was printed in *21st Century Science & Technology,* Winter 2001-02. Written in 1938, the article addresses one of the most central issues in natural science, and one of immediate relevance to potentially revolutionary research now going on in biophysics and related areas today.

Since ancient times, those who have sought to comprehend the organization of our universe, have generally distinguished among three main *classes* or *domains* of phenomena: *First,* phenomena occurring in inert or *non-living* matter, outside of the action of living organisms. *Second, living processes,* i.e., the domain of biology. And *third,* processes connected with the cognitive activity of the *human mind.*

This three-fold division of the universe into nonliving processes, living processes, and the processes connected with human reason, has occasioned much confused and often unproductive controversy in the course of history. On the other hand, it is exactly the *paradoxical relationship* of the three domains, when approached from the rigorous standpoint typified by Gottfried Wilhelm Leibniz and by Plato before him, that has been at the center of the most profound revolutions in science over 2,000 years. Let us first look at the relationship between the *first* and *second* domains, which was the main (but not the only) focus of Vernadsky's work.

Molecular Biology Evades the Issue

It ought to be the main task of the life sciences, to investigate precisely those features of living processes, which distinguish them from all non-living processes. Yet, with the triumph of reductionist thinking in natural science, and above all with the vast development of molecular biology since the middle of the 20th Century, the border-line between the living and non-living has become more and more fuzzy, or even non-existent, in the minds of scientists.

Thus, biologists nowadays are generally accustomed to regard a living cell more or less as a "molecular machine," whose workings, however complicated, can be understood in analogy with Alan Turing's generalized conception of a mechanical procedure (Turing machine). But at the same time, the almost mind-boggling wealth of combinatorial detail, which the techniques of molecular biology have amassed concerning the biochemistry of living organisms, serves to distract attention from the really fundamental questions in biology, which have *not* been answered, and which are often *not even being posed.*

We are reminded of the sly student at an oral examination, who, when confronted with an uncomfortable question, proceeds to deliver a long and elaborate answer . . . to a *different* question!

What is life? Wherein lies the *essential difference* between living and nonliving processes? Is it merely one of "complexity"? Are living cells merely special cases of "aperiodic crystals," whose properties can be understood on the basis of modern quantum physics, as Erwin Schrödinger originally suggested in his famous 1944 essay? Do living organisms constitute "self-organizing dissipative structures," analogous to the convection cells formed spontaneously in a heated fluid, and obeying the statistical laws of Ilya Prigogine's "nonequilibrium thermodynamics"?

Apart from the details of these and other modern theories, they all manifest a nearly universal tendency in our age, namely to assume *either* 1) that there is no *really fundamental* distinction between living and nonliving processes, and that living processes can ultimately be reduced to the *same* set of principles of physics and chemistry, which govern nonliving processes; *or* 2) that whatever distinctions *do* exist, can be characterized within the framework of physics and chemistry *as presently understood.*

By contrast, what contemporary science, with few exceptions, refuses to admit, is the presence of a *third* possibility, namely: 3) that there really *does* exist an absolute, fundamental distinction between living and nonliving, but that it involves *a higher principle, not expressible* on the basis of the concepts and principles of physics and chemistry *as presently understood.*

It is exactly this third alternative, for which Vladimir Vernadsky, in the cited article, presents overwhelming, conclusive evidence.

The failure to recognize this third alternative—despite Vernadsky's work and despite the fact, that the essential point involved was familiar long before to Leibniz and even to Plato—reveals an *elementary methodological error,* pervading both modern molecular biology and the attempted approaches of Schrödinger, Prigogine, and others to the physics of living processes.

The Error of Reductionism

The nature of the error was clearly identified, over 500 years ago, by the great Renaissance thinker Nicolaus of Cusa, in his critique of Archimedes' work on the squaring of the circle: In attempting to approximate a circle by a series of inscribed regular polygons of increasing number of sides, we

appear to come closer and closer to the circle, but we can never actually *reach* the circle. Even if the number of sides of the polygon were hypothetically to become *infinite,* it would still not resolve to complete *identity* with the circle, because the circle constitutes a higher *species* of geometrical existence. The circle embodies a *higher principle,* namely that of continuous *rotational action,* which is entirely absent from the linear domain of the polygons. Although the polygons can be constructed from the circle—and in that sense the circle subsumes, as a "higher species," the "lower species" of the polygons—there is no way to arrive at the circle from the polygons.

Nevertheless, geometers and others expended untold efforts, down through the centuries, in fruitless attempts to *square the circle,* making the same type of mistake as those who, from the time of Pythagoras on, refused to accept the existence of *incommensurable magnitudes* in geometry. The same error emerged later in the resistance to Leibniz's notion of the infinitesimal calculus, and in the bitter opposition by Kronecker and others to the Georg Cantor's introduction of the transfinite numbers.

So also, natural science today (and biology in particular) is crippled by the failure to take account of the sort of unidirectional, hierarchical distinction and relationship between *lower and higher principles* in the universe, that Nicolaus of Cusa illustrated 500 years ago, using his pedagogical discussion of the circle and polygons.

The attempt of molecular biologists to treat living organisms as "molecular machines" exemplifies the problem perfectly.

There is no doubt that the vast and intricate arrays of biochemical reactions and related processes, identified by modern molecular-biological methods, *do* actually take place in living cells. It *appears* also to be the case, that changes in a living cell, can always be *correlated* in some way with changes in the configurations and motion of molecules. There is thus little doubt, that molecular biology can *approximate* the workings of living processes—perhaps even up to the point of "asymptotic convergence"—in terms of ever more extensive mappings of the purported "molecular machinery" of cells. The latter corresponds, in a methodological sense, to Nicolaus of Cusa's polygons with increasing numbers of sides. Now comes the difficulty: None of the molecular-biological approximations, taken by itself, can account for the functional characteristics of living matter in the biosphere, as demonstrated by Vernadsky. We never get, so to speak, to the "living part," i.e., to the unique characteristic of *action,* which distinguishes living from nonliving processes. That higher characteristic, bears an analogous relation to the domain of "molecular machinery," as rotational action bears to the straight-line action embodied in Nicolaus of Cusa's polygons.

To go beyond this, at first glance purely *negative* observation concerning the limits of reductionist methods, let us go back to the three-fold division of the universe and have a look at the specific contribution of Vernadsky and of his successor in this matter, Lyndon LaRouche.

Living Matter in the Biosphere

A scientific understanding of the three-fold division of the universe begins, when we abandon the naive tendency to interpret the basis for the distinctions between the three domains, in terms of the supposedly inherent properties of *objects per se*—for example, living and nonliving objects. What we are really dealing with, as Leibniz emphasized, is distinct *classes of physical principles,* all acting upon the universe at the *same time,* and which stand in a well-defined hierarchical relationship to each other. That hierarchical relationship is the immediate focus of Vernadsky's life work.

Consider the characteristic *activity* of living matter on the Earth, as exemplified by the case of plants. Living plants grow and maintain themselves by virtue of their ability to absorb water, minerals, and other inorganic materials from the soil, and gaseous molecules from the atmosphere, and to work up this nonliving material into living tissue. Thereby, nonliving matter has been transformed into living matter!

Looking at this on the microscopic level, the question poses itself: What is the nature of the *physical change* which occurs during this transformation? How does an atom of nitrogen, for example, which is now part of the plant's living tissue, differ from its earlier existence in the mineral fertilizer the farmer put into the ground?

Present-day molecular biologists would characterize the change as merely one of a different chemical binding of the nitrogen atom in the living tissue—for example in a protein or other organic molecule—as compared to the inorganic compound it was part of in the fertilizer. They might hasten to add, that same organic binding could also be realized in a laboratory just as well, outside of living tissue. Hence, in their view, there is no change on the atomic or molecular level which could be shown to be unique to living processes only.

Some modern biophysicists, however, would rightly disagree with the simple-minded chemists' conclusions. They will point out, for example, that the physical state of an atom depends upon much more than simple chemical binding; the behavior of atoms and molecules in living tissue is modified by a common quantum-electromagnetic field, which imposes a coupling of processes occurring at distant locations within living tissue. Exactly that feature, is a matter which is an area of ongoing, experimental investigation.

Responding in this way, however, both the chemist and the biophysicist would have failed to point out the most elementary feature of the process at issue, namely: the *active role* played by the living organism itself, in *imposing,* so to speak, a *higher state of organization* upon that nonliving matter. In this way, the organism acts as the *physical cause* of *a*

continuous and highly directed transformation of its environment.

It was Vladimir Vernadsky, who most clearly recognized and demonstrated the nature of that biogenic transformation, by shifting the focus of the investigation from the level of isolated individual organisms, to the aggregate of *all* living matter existing on the Earth at one time, and by studying the *impact* of living matter upon its environment (the biosphere) over the *longest time scale* which is available to precise observation: geological time. Thus, in place of the perilously abstract question "What is life?" Vernadsky substituted a concrete geological question—one concerning the specific role of living matter in the geological history of the Earth.

What Vernadsky had accomplished for the relationship of living to nonliving processes in the biosphere, LaRouche has done for uniqueness of human reason relative to living processes in general.

Vernadsky's main conclusions, based on the analysis of an enormous body of empirical data and elaborated in the said article and other writings, can be summarized as follows:

1. In the course of evolution, the aggregate "free energy" of the living matter in the biosphere—its ability to do work on the environment—has been constantly increasing.

2. As a result of that increase in free energy, living matter has become the *most powerful geological force* in the biosphere—even though the total mass of the living organisms themselves, remains a nearly *infinitesimal fraction* of the total, growing mass of matter directly and indirectly affected by their activity within the biosphere.

3. In the course of evolution, living matter has constantly expanded the "envelope" of the Earth that is populated by living organisms—i.e., the biosphere—extending it upward into the atmosphere, into the depths of the oceans and ever deeper into the Earth's crust. That process of expansion of the biosphere, occurs through the "colonization" of new regions, formerly not inhabited by living organisms, in the course of which ever more of the nonliving matter and energy of the Earth's crust and atmosphere is transformed and caught up into the geobiochemical cycles connected with the metabolic and related activity of living organisms—what Vernadsky called the "biogenic flux of matter and energy in the biosphere." Vernadsky furthermore laid the basis for precise *measurement* of the development and expansion of the biosphere.

4. The capacity for this specific sort of *evolutionary development,* leading to a continual increase in the free energy of living processes in the biosphere, is unique to living organisms and is not found in the nonliving domain. Throughout the geological history of the Earth, the basic processes in the nonliving matter of the biosphere have remained virtually the same over billions of years, except insofar as they have been modified through the influence of living organisms.

Analysis Situs

The above conclusions, based upon the analysis of an enormous accumulation of empirical evidence, demonstrate the existence of an *absolute, unbridgeable division* between nonliving and living matter in the biosphere. Vernadsky repeatedly emphasized that the distinction thus proven, constitutes a *scientific fact.* It is not the product of philosophical speculation nor of any scientific theory, but constitutes a feature of *reality* which any scientific knowledge must take account of.

But Vernadsky adds a crucial additional conception: With the emergence of man and human society, the biosphere has entered a new stage, which Vernadsky called the "noösphere," in which *human creative reason* becomes increasingly the dominant, guiding influence in the further expansion and development of the biosphere; including its eventual extension beyond the Earth, into the Solar System and beyond.

Thanks to Vernadsky's work, we have far clearer *empirical proof* for Leibniz's view of the three-fold division of the universe—and especially the distinction between nonliving and living domains—than was ever possible before.

Life, as embodied concretely in the geological activity of living organisms on the Earth, embodies a *principle* or set of principles, that are distinct from, and demonstrably *superior* to, the principles governing the behavior of nonliving matter. In this way, living processes are able, increasingly, to *command* and transform nonliving processes so as to increase the aggregate *power* of living matter within the biosphere. It is as if, echoing the words of *Genesis,* God had granted life *dominion* over the inorganic domain!

As regards the demonstration of the fourth point, concerning the noösphere and the role of human reason, Vernadsky's work remained incomplete. In this respect the direct continuation and completion of what Vernadsky had begun, lies in the work of the American economist and statesman Lyndon LaRouche. Among other things, LaRouche showed:

1. The absolute distinction between man and all other forms of life in the biosphere, is empirically demonstrated by the fact, that the human species has been able, through deliberate changes and improvements in the mode of individual and social activity vis-à-vis the biosphere, to increase its overall population-potential by over a *thousand-fold* in the course of prehistoric and historical development. No other

living species has demonstrated that ability.

2. The *cause* of that thousand-fold increase, in the course of history, in the size and quality of the human population that can maintain itself on the Earth, is located solely in the *creative powers of individual human reason* to discover, assimilate, and apply *new scientific principles* and analogous discoveries of principle in art and statecraft, with the effect of improving man's power to command the forces of nature (technology).

3. The action of individual creative reason, upon which the capacity of the human species to effect successive increases in its population potential is based, has a specific and completely unique form. It lies in the ability to deliberately seek and discover errors or imperfections in the commonly accepted assumptions underlying the practice of a society, and to correct or supplement those assumptions, through the discovery and validation of a new universe principle, shown to govern the universe—and which was either contradicted, or at least not accounted for, by the previously existing assumptions or axioms of thought.

4. Acts of original *creative discovery* and acts of *creative learning and problem-solving*—of the sort needed to adequately assimilate and apply such discoveries (in the form of new technologies) in the successful practice of society—are generated solely within the "sovereign" mental processes of *individual human beings.* Thus, the process of increase of the population potential of the human species, occurs as a successive integration of specific creative mental acts by individuals, which have the net effect of transforming the overall practice of society. This *unique historical relationship of the individual to the whole* is found *only* in human society and *only* in connection with human reason; it is entirely lacking in both the other two, lower domains of the universe.

What Vernadsky had accomplished for the relationship of *living* to *nonliving processes* in the biosphere, LaRouche has done for uniqueness of *human reason* relative to *living processes in general.* Thereby, LaRouche brought the questions, *What is human reason?* and *What is the absolute distinction between man and all other living species?* into the domain of rigorous *empirical-scientific demonstration* and *measurement*—as opposed to what had been commonly regarded as the merely "subjective" realms of religious belief and philosophical speculation.

Combining LaRouche with Vernadsky, we obtain a most lucid and powerful overview of the three-fold division of the universe.

What we are dealing with, is the differentiation among three, interconnected *classes* or groups of *physical principles* constituting human knowledge of the universe. For convenience let us designate them as follows:

A equals physical principles pertaining to nonliving processes generally; *B* equals physical principles pertaining to the unique characteristics of action of living processes, relative to nonliving processes; *C* equals physical principles pertaining to the unique characteristics of human reason.

Note the following paradoxical, but crucial point: Physical principles, insofar as they are valid principles of human knowledge, must be *universal:* they must, at least implicitly, apply to the universe *as a whole.* The unity and coherence of the universe (and of human knowledge) would thus seem to demand, that (for example) the principles governing nonliving matter (class *A*) must also apply in some way to living processes; and conversely the principles of living processes (class *B*) must also apply to nonliving processes; and similar for class *C.* But doesn't this contradict the *absolute, fundamental distinction* between living and nonliving processes, and between living processes and human reason, demonstrated by Vernadsky and LaRouche, and which was the whole point of our discussion so far?

Recalling Vernadsky's demonstration of the dominion of living processes over nonliving matter in the biosphere, and LaRouche's related proof for human reason, shows the way out of the paradox.

The principles of living processes are principles for the *action* by which living matter "conquers" and transforms nonliving matter, as the increasingly dominant geological force in the biosphere. Similarly, man's demonstrated power to deliberately increase his per-capita power to command the forces of nature, through the exercise of human reason, points to the implicit *universality* of the principles underlying human reason. Insofar as the universe "obeys" human reason, even nonliving matter is implicitly subject to the principles of human reason, albeit in a different way than the human mind itself. Conversely, living matter, including the brain tissue which is an indispensable substrate for human mental activity, is composed of the same atoms and molecules as nonliving matter; and living matter appears subject to the principles of class *A,* while not being completely determined by them.

What we are therefore dealing with, is a *multiply-connected universe* in the sense of Bernhard Riemann: The principles of classes *A, B, C* are all acting on one and the same universe, simultaneously and (implicitly) at every location. But at the same time, the three classes of principles stand in a definite *hierarchical* relationship $A < B < C$ to each other, in terms of *physical power* or what Cantor called *Mächtigkeit,* and as evidenced by the growing dominion of living over nonliving matter, and of reason over the living and nonliving domains within the biosphere. Being of different *Mächtigkeit,* the classes *A, B, C* are strictly differentiated from another; and yet, an overall harmony exists between them, insofar as they jointly define a self-developing, anti-entropic universe.

This sort of relationship of classes of physical principles, which is well-defined and yet cannot be expressed in logical-deductive terms, is the subject of what Leibniz called "*analysis situs.*" Vernadsky's work is a brilliant application of that method, to the empirical domain of the naturalist. . . .