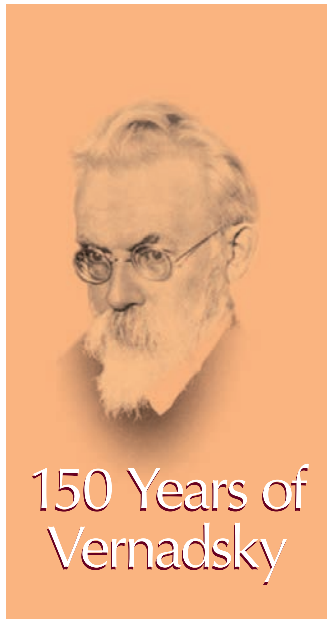
Biospheric Energy-Flux Density

by Benjamin Deniston



Tyrannosaurus Rex

In a February 5, 1928 speech given to the Society of Naturalists of Leningrad, Vernadsky made a series of concrete arguments that go directly against the core ideology of what is generally recognized as the modern environmentalist, or "green" movement. The specifics of the argument made there have crucial implications for today.

One year later, Vernadsky included this speech in the 1929 French publication of his seminal work, *The Biosphere*. According to Vernadsky, "I attach, as an appendix to the French translation [of the Biosphere], my speech, 'The Evolution of Species and Living Matter,' which seems to me to supplement the ideas established in *The Biosphere*".[1]

Here Vernadsky directly addresses the evolution of life on Earth from the standpoint of his concepts of the distinct, but interacting phase-spaces of the biosphere, lithosphere, and noösphere, concluding that evolution has a direction, and a specific, irreversible form of progress:

> This biogeochemical principle which I will call the second biogeochemical principle can be formulated thus:
>
> The evolution of species, leading to the creation of new, stable, living forms, must move in the direction of an increasing of the biogenic migration of atoms in the biosphere…
>
> [This second biogeochemical principle] indicates, in my opinion, with an infallible logic, the existence of a determined direction, in the sense of how the processes of evolution must necessarily take place… All theories of evolution must take into consideration the existence of this determined direction of the process of evolution, which, with the subsequent developments in science, will be able to be numerically evaluated. It seems impossible to me, for several reasons, to speak of evolutionary theories without taking into account the fundamental question of the existence of a determined direction, invariable in the processes of evolution, in the course of all the geological epochs. Taken together, the annals of paleontology do not show the character of a chaotic upheaval, sometimes in one direction, sometimes in another, but of phenomena, for

1. See Vernadsky's introduction to the French translation of *The Biosphere*. For an English translation of the introduction and the speech, see "The Evolution of Species And Living Matter," translated from French by Meghan Rouillard, *21st Century*, Spring-Summer 2012. All indented quotes below are from this translation of Vernadsky's speech on evolution.

which the development is carried out in a determined manner, always in the same direction, in that of the increasing of consciousness, of thought, and of the creation of forms augmenting the action of life on the ambient environment.

This concept runs in direct contradiction to the entire British reductionist school of thought which has increasingly dominated science over the course of the past century, and underlies the entirety of the founding of the modern environmentalist movement which has corrupted the morality of much of the population today. (See Box.)

This is not an academic debate: the governing beliefs in science and society have real-life consequences and effects. As Vernadsky clearly knew from his unique work on the concept of the noösphere, human progress can be studied in terms of the physical effects of scientific and cultural thoughts and discoveries. There are knowable benefits, or losses, resulting from either the successes, or failures, of humanity to progress scientifically and technologically.

For example, despite the depths of the immediate hyperinflationary crisis (the growing actual unemployment, the long-standing collapse of the productive capabilities of the trans-Atlantic region, unacceptable levels of global poverty and starvation, a looming collapse of food supplies for even developed nations, etc.), there is still a persisting delusion of investing in so-called "green jobs" and the "green economy," *activity inherently characterized by actually lowering the productive capabilities of the population per capita, necessarily resulting in mass death and suffering.*[2]

Understanding the principles underlying a scientifically definable nature of progress is of utmost importance for the immediate state of mankind. One path towards illustrating this principle is taking up Verandsky's challenge to identify the relationship between the overall progressive

2. Mass genocide is not simply a consequence of the policy, but the explicit intention, as stated and demonstrated repeatedly by the founders and orchestrators of the green movement. See, "Behind London's War Drive: A Policy To Kill Billions," by Nancy Spannaus, *Executive Intelligence Review* magazine, November 18, 2011.

British Reductionism: Evolution from The Standpoint of Imperialism

One year after Vernadsky gave his Feb. 5, 1928 speech, and the same year as its French publication, British imperial establishment figures H. G. Wells and Julian Huxley published a book, *The Science of Life*, in which they reiterated the British school's rabidly reductionist view of evolution. This view was also clearly expressed by Alexander Oparin, with whom Vernadsky was directly at odds over the fundamental nature and origin of life. Wells and Huxley write:

> Variation is at random, selection sifts and guides it, as nearly as possible into the direction prescribed by the particular conditions of the environment. Once we realize this, we must give up any idea that evolution is purposeful. It is full of apparent purpose; but this is apparent only; it is not real purpose. It is the result of purposeless and random variation sifted by purposeless and automatic selection. In brief, we are confronted with the gravest theological difficulties if we too light-heartedly set out to see purpose in Evolution. The wiser and saner course is to acknowledge our ignorance of ultimate causes and designs.

The concluding sentence of this quote is reminiscent of Adam Smith's famous quote from his *Theory of Moral Sentiments*:

> To man is allotted a much humbler department... Nature has directed us to the greater part of these by original and immediate instincts. Hunger, thirst, the passion which unites the two sexes, the love of pleasure, and the dread of pain, prompt us to apply those means for their own sakes, and without any consideration of their tendency to those beneficent ends which the great Director of nature intended to produce by them.
>
> —Adam Smith, *Theory of Moral Sentiments,* 1759

The view of Huxley and Wells sounds much closer to the stated social doctrine of the British Empire, imposed on populations for cultural and political effects, and less like valid scientific thought. This doctrine holds as a central axiom that there is no knowable purpose or inherent progress in the universe, and, if there were, mankind would have no business attempting to know the purpose, much less consciously intervene to determine his own fate. That is the doctrine the British Empire has fought to impose on the general population of the world in one form or another, be it in science, or in economics.

See Meghan Rouillard's article in this issue: "A.I. Oparin: Fraud, Fallacy, or Both?"

nature of the biosphere as a whole—as understood from his perspective of biogeochemistry and the role of living species—and the evolutionary change of living species within his understanding of the biosphere.

> The evolution of species, leading to the creation of new stable, living forms, must move in the direction of an increasing of the biogenic migration of atoms in the biosphere… the agreement of evolution with [that principle] is evident, as it always seems to manifest itself, in the analysis of the paleontological annals.
>
> How did this agreement occur? Does it follow from a blind combination of circumstances or, indeed, from a more profound process, determined by the properties of life-incessant processes, always the same in their manifestations in the course of the entirety of the geological history of the planet?
>
> The future will decide this.

In honor of 150 years of Vernadsky, these questions are now re-assessed from the perspective of the 85 years of scientific work accomplished since Vernadsky delivered this speech.

The Conceptual Groundwork

Addressing Vernadsky's challenge will require drawing upon both the body of his life's work, but also the related discoveries of Lyndon LaRouche. LaRouche's founding of the physical science underlying the growth and development of human societies, *physical economics*, uniquely converges upon the same subject of study as Vernadsky's noösphere in a very important way.

Specifically, LaRouche developed the concept of *energy-flux density*, initially as an indispensable metric of economic progress. Measuring energy throughput, per unit time, per unit area, energy flux density proved to be one of the factors most intimately correlated with economic growth and progress.[3] Compare, for example, the vastly superior energy densities of nuclear reactions, fission and fusion, with chemical combustion (and especially with the ridiculously low energy density of wind and solar power systems).

Since demonstrating that *increasing* the energy-flux density of an economic system is critical to progress, LaRouche indicated that this characteristic could be generalized, as a property of other developing (anti-entropic) systems as well, such as in the development of life on Earth, or perhaps even in certain astrophysical processes. The "energy" measured will obviously be of a different form, but the general property of increasing density of action and change should remain as an indicator of progress.

As to Vernadsky's discoveries, while rejecting the fraud of Alexander Oparin, he fully promoted and continued the work of Louis Pasteur on what he referred to as the principle of Francesco Redi: *life only comes from life*.[4] In Vernadsky's work, living organisms not only express a distinct universal principle, but their domain of action, the biosphere, operates at a quantitatively and qualitatively higher rate of activity compared with that of the surface of a planetary body unaffected by life (the lithosphere). Thus the biosphere is superior, and has transformed the face of the planet at speeds and in ways impossible in the domain of the lithosphere devoid of life. Furthermore, the biosphere, driven by the evolutionary advance of life, has done this at successively higher and higher rates, defining a true direction and measure of progress in the history of life on Earth.

Moving beyond the biosphere, Vernadsky also recognized that human creative thought is a force absolutely distinct from anything expressed by simply animal life as such. The domain of action of scientific discoveries, of creative of human thought, identified as the *noösphere*, expresses a rate of activity growing much faster than that of the biosphere, overtaking and transforming the biosphere, raising it to higher rates of activity than the untended biosphere could ever accomplish.[5]

Overall, Vernadsky's revolutionary approach to evolution did not come from a foundation built on the characteristics of individual organisms, but rather sprang from his unique concept of the biosphere, and its tiered interaction with the lithosphere and noösphere. Vernadsky saw an overly narrow focus on individual species, abstracted from the context of the biosphere, as artificially limiting the investigation and thus preventing a fuller understanding of the nature of life.

> It is also evident that the evolution of species is correlated with the structure of the biosphere. Neither life, nor the evolution of its forms, would have been able to

3. For an introduction into LaRouche's science of physical economics see his *So, You Wish to Learn All About Economics?*, New York: New Benjamin Franklin Publishing House, 1984.

Based on LaRouche's method, from the late 1970s through 1987 the economic staff of *Executive Intelligence Review* magazine (founded by LaRouche), produced a series of regular economic reports and forecasts which far surpassed official government and other private economic analyses produced over the same time period: the *EIR Quarterly Economic Report*.

4. See Vernadsky's three essays on the material-energetic distinction between life and non-life, "On Some Fundamental Problems of Biogeochemistry," "Problems of Biogeochemistry II," and "On the States of Physical Space." Available in the *21st Century* Winter 2005 (http://bit.ly/AxeuMd), Winter 2000 (http://bit.ly/wrL86T), and Winter 2007 (http://bit.ly/zYLPZY) issues.

5. For Lyndon LaRouche's analysis of the principled importance of Vernadsky's work from the standpoint of the historical continuity of the development of extended-European science with the history of science itself understood from the standpoint of physical economic progress in terms of the fundamental cultural development of human society. See LaRouche, "Vernadsky and Dirichlet's Principle", *EIR*, May 18, 2005.

> exist independently of the biosphere, nor to be divided from it as separated natural entities.

This connection is intimately expressed in what Vernadsky identified as the *biogenic migration of atoms*, the continuous consumption, respiration, and other forms of material-energetic exchange between living organisms and the surrounding environment.

According to this understanding, living organisms become special kinds of singularities in the biosphere, composed of continuous fluxes of atoms, coming from, and returning to, the surrounding environment, but also, *more crucially, they are the energetic drivers of the entire biosphere, constantly shaping it, maintaining it, and bringing it to a more energy-dense and more highly organized state by their activity*. If living organisms were to stop their activity, the surface of the Earth would rapidly, in a geological "moment" of time, approach that of a planetary body like Mars.

Vernadsky shows, on this basis, that the evolution of living organisms is inseparable from, and the driving force in the development of the biosphere as a whole, while at the same time, an integral component *of* the biosphere, completely dependent upon it. Therefore, instead of solely focusing on the visible morphological structure of the organism, as is the practice of the standard biologist or paleontologist, the study of the material and energetic interaction of the living organism with its surroundings, the study of *biogeochemistry*, becomes absolutely indispensable in understanding the nature of the direction and progress in evolution.

> From that standpoint, it is easy to convince oneself that the fundamental conceptions of biology must be submitted to radical modifications.
>
> The species is habitually considered, in biology, from a *geometrical* point of view; the form—*the morphological characteristics*—are primary, in terms of importance. In biogeochemical phenomena, on the contrary, this is reserved to number, and species is considered from an *arithmetic* point of view.…
>
> In biogeochemical processes it is indispensable to take into consideration the following numerical constants: the mean weight of the organism, its mean *elementary chemical composition*, and its *mean geochemical energy*, that is to say the facility with which it produces displacements, otherwise called "the migration" of chemical elements in the living environment.

The current, abstracted view of a species, defined solely by its visual appearance (or by its DNA), while not useless, is not sufficient to define the history of life on the planet. What is needed is a study of the totality of a species, and of various species, their interactions, and their ability to change and transform the surrounding environment. The action of the species in affecting the entire process of the biosphere becomes the primary point of reference, especially when that action is understood from its contribution towards creating a new, higher-order state of the biosphere.[6]

Vernadsky on Evolution

From this vantage point, Vernadsky converges on a measure of progress in evolution that falls under the concept of *energy-flux density* independently developed by LaRouche.

The ability of organisms or species to perform action in the biosphere Vernadsky called *geochemical energy*. In this way the displacement of chemical elements from one location to another, or from one form to another, by organisms can be measured. In his "Evolution of Species and Living Matter," Vernadsky focuses on three forms of this *biogenic migration of atoms*.[7]

1. **The basic biogenic migration created by living organisms:**
   The living organism during its life, is an incessant current, a whirlpool of atoms which come from the exterior and return there. The organism lives as long as the current of atoms subsists. The current encompasses all of the material of the organism. Each organism on its own, or all organisms taken together, continually creates, by respiration, nutrition, internal metabolism, and reproduction, a biogenic current of atoms, which constructs and maintains living matter. In sum, it is the essential form and principle of the biogenic migration.
2. **The rate or intensity of the biogenic migration of atoms:**
   Evidently, the effect of the entire biogenic migration does not depend directly on the mass of living matter. It does not depend any less on the quantity of atoms than on the intensity of their movements in intimate relation with life. The biogenic migration will be all the more intense as the atoms circulate more quickly; this migration can be very diverse, even while the quantity of at-

6. This is similar to a physical economic pedagogy of LaRouche. Taking a standard auto mechanic in the economy, can we really define the value of his actions, his productivity, solely by the actions he performs as such? Say he makes the exact same repair on the exact same car of two different individuals. By standard monetary economic accounting, both repairs would supposedly have the same value, the same hours of labor, parts, etc. However, if the first individual is then able, by aid of the mechanic's actions, to continue his work asset-stripping industrial firms, while the second is then able to continue his work producing tractors for farming production, the *physical economic* value, defined by the contribution of the worker to the productive capabilities of the entire economy, is drastically different.

7 Vernadsky also cites a fourth kind, but does not elaborate on it in detail in that location.

oms encompassed by life is identical. That is the second form of biogenic migration, in relation to the intensity of the biogenic current of atoms.

3. The biogenic migration due to technological developments:
The migration of atoms, also sustained by organisms, but which is not genetically or immediately related to the penetration or to the passage of atoms through their body. This migration is provoked by technological activity. It is, for example, determined by the work of burrowing animals, of which we notice traces since the most ancient geological epochs, by the consequences of the social life of building animals, termites, ants, and beavers.

These are three expressions of the geochemical energy of living organisms in the biosphere. The organism, or species, is understood, thus, not solely by its morphological structure, but by its power to effect change, specifically measured in terms of the growth and expansion of the biosphere over the lithosphere, as, for example, measured in these three forms of biogenic migration.

Focusing on evolution specifically from his understanding of the inseparable material-energetic interdependency between living organisms and the biosphere, Vernadsky formulates what he calls his *second principle of biogeochemistry* (different from his three types of biogenic migration).[8]

> Naturally, the mechanical condition which determines the necessity of this character of atomic migration, is maintained uninterrupted in the course of all geological time and the evolution of forms has always taken this into account. This mechanical condition which caused this biogenic migration of elements is due to the fact that life constitutes an integral part of the mechanism of the biosphere and, fundamentally, it is the force which determines its existence. It is also evident that the evolution of species is correlated with the structure of the biosphere. Neither life, nor the evolution of its forms, would have been able to exist independently of the biosphere, nor to be divided from it as separated natural entities. Starting from this fundamental principle, and the fact of the participation of evolution in the ubiquity and pressure of life in the current biosphere, we are well situated, concerning the evolution of living forms, to pose a new biogeochemical principle. This biogeochemical principle which I will call the second biogeochemical principle can be formulated thus:
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> The evolution of species, leading to the creation of new stable, living forms, must move in the direction of an increasing of the biogenic migration of atoms in the biosphere.

Vernadsky argues that even if the total mass of living matter were to remain constant,[9] over evolutionary time there will still be an increase in the *rate* of the biogenic migration, that is, increase in the biogenic flux, per mass of living matter, per unit of time. Or, in LaRouche's terms, an increasing energy-flux density of the biosphere.

According to Vernadsky, this should be the key characteristic of the directional progress of evolution. Since Vernadsky's accomplishments, decades of new evidence have accumulated, providing a new basis to conclusively demonstrate his concept of the nature of irreversible progress governing the development of life on Earth.

The New Evidence

Various proxies provide indications of the conditions of the biosphere during past periods, and when viewed in light of Vernadsky's concept of the second biogeochemical principle, can provide excellent support for his views on evolution.[10]

First, evidence of the geochemical energy of species from previous periods is sought. This is not directly measured in absolute terms; rather, various proxies are investigated, either from the geological and biogeochemical records, or from descendants or holdover species from previous periods. An estimate of the geochemical energy of different taxonomic *classes*, for example, as opposed to species, often proves more insightful, because this taxo-

8. Vernadsky described his first biogeochemical principle as "the pressure of life," specifically: "*the biogenic migration of chemical elements in the biosphere tends towards its most complete manifestation.*" This is expressed, for example, in the tendency of life to expand into every location of the biosphere that it is technologically and energetically capable of occupying.

9. Although in this 1928 speech Vernadsky discusses a relatively fixed total mass of living matter over time, by 1938 he argues that the total mass has increased over evolutionary time. Given the fact that estimates of even the current living biomass vary, speculations on the total living biomass of previous geological periods will not be discussed here, and the evidence for changes in the rate of activity per unit mass will be investigated instead.

10. A significant amount of supporting evidence for Vernadsky's second biogeochemical principle is provided by a relative handful of studies from the past three decades. The work of the authors of these studies is of great significance for Vernadsky's concept, and, when understood from his science of biogeochemistry, provide additional support for a long-overdue fundamental revolution in the scientific understanding of the history of life. The fact that such a revolution has not already occurred, can only be attributed to the insistence on interpreting the evidence from within the accepted framework of ideological biases, typified by the continuing legacy of the British reductionist school, as expressed in, for example, Thomas Gould's unoriginal arguments attacking the concept of direction and progress in evolution. Science is often held back not by the quality of the evidence, but by the quality of the assumptions by which the evidence is interpreted. A revolution in the understanding of evolution will require the perspective of Vernadsky's biogeochemical analysis, and the independent work of both Vernadsky and LaRouche on the science of anti-entropic systems.

nomic level often specifies key characteristics which define the geochemical energy of an entire set of species.[11] Key proxies are found in indications of:

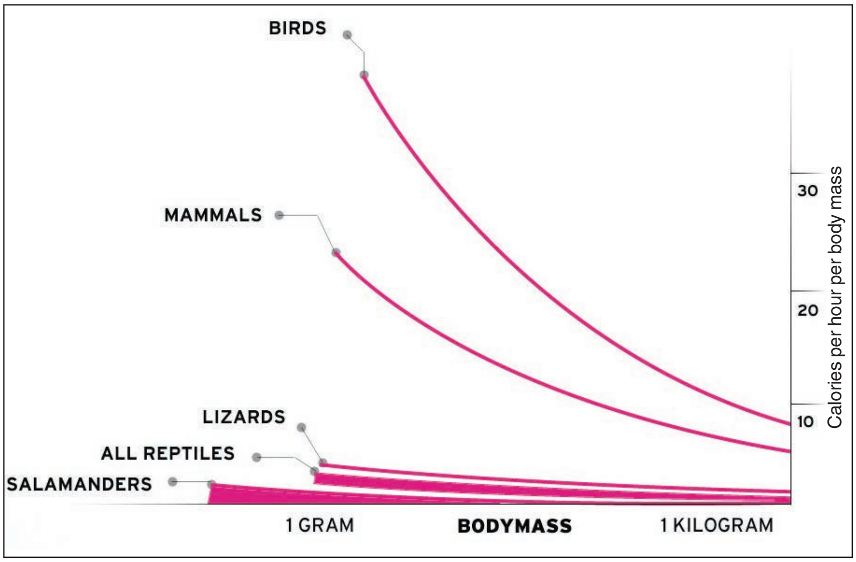
1. The metabolic rates of organisms.
2. The development of more energy intensive modes of life, such as actively pursuing and consuming other animals for food, predation.
3. The technological ability of organisms to freely move through the biosphere, expand their reach into new domains, and to alter the surrounding environment through their actions.

These are understood from their correspondence with Vernadsky's three forms of biogenic migration listed above.

Second, species tend to rise and fall in rough correspondence. This parallel turnover can be especially clear when examining the middle-level classifications (around the order/class taxonomic levels), pointing to the possibility that the correspondence indicates a characteristic geochemical energy associated with interacting and interdependent sets of species (or orders/classes, etc.). The progressive nature of the development of life is most clear from this perspective of sets of various interacting orders/classes defining large-scale orderings to the material-energetic structure of the biosphere across geological time (both in terms of the rate of biogenic migration, but also, possibly, in variations in the specific chemical elements in circulation, and in the biological and chemical structures formed by them). As will be seen below, there is remarkable evidence that specific biospheric sets define periods of relative stability across long periods of geological time, indicating a single level, or stage to the entire biospheric system.

Third, from one stage to the next, the geochemical energy of the biospheric system increases, specifically in terms of the biospheric energy-flux density, demonstrating Vernadsky's principle of progress in evolution.

Figure 1
Metabolic Rate



Adapted from "Amphibians and Reptiles as Low-Energy Systems," by F. Harvey Pough, in *Behavioral Energetics: The Cost of Survival in Vertebrates*, Ohio State University Press, 1983.

For any given species, or certain classes, the metabolic rate of an organism will scale with the size of the organism in a specific, fixed way. However, different species or classes of organisms will have different values of the entire class, such that comparing examples of the animals of the same weight from different classes yields different metabolic rates. Here metabolic rates are expressed per unit mass of various classes and species of vertebrate tetrapods.

Metabolic Rates and Biogenic Migration of the Second Type

To start, compare the metabolic rates of different classes of vertebrate animals: for example, today's birds, mammals, reptiles, and amphibians. Their average metabolic rates show a clear succession (see Figure 1). A lower metabolic rate translates into lower respiration and consumption, and thus a lower geochemical energy (a lower rate of displacement of the surrounding material of the biosphere).

The question then is: how have the metabolic rates (and thus the geochemical energy) changed over the course of evolution?

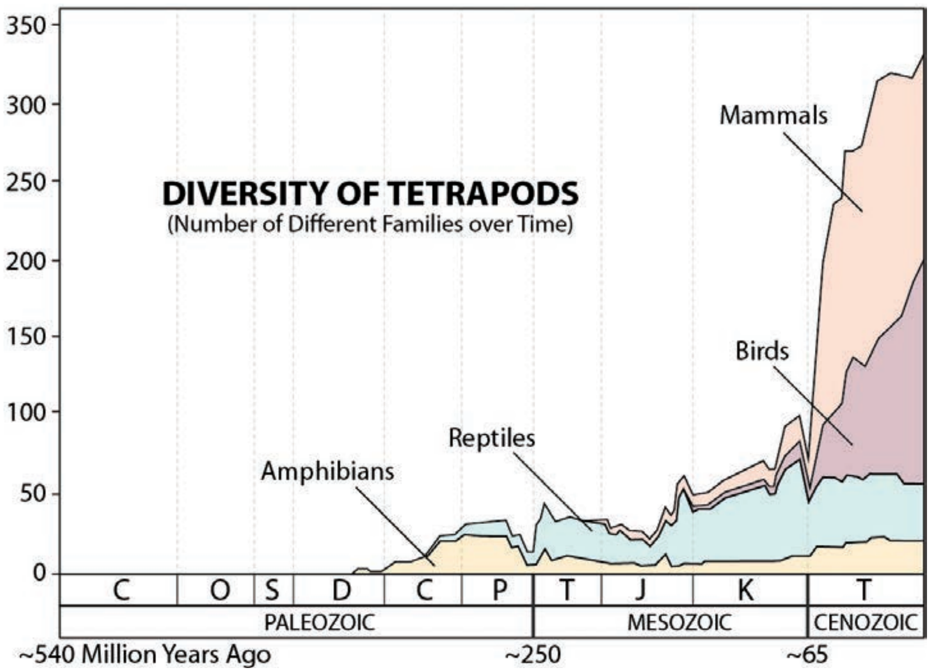
On a larger scale, it has been known that the past 400 million years have been characterized by the succession of the age of the amphibians (lasting until 250 million years ago), to the age of the reptiles (lasting until 65 million years ago), to the age of the mammals (see Figure 2). However there are many intricacies (such as the question of whether dinosaurs were warm- or cold-blooded) which prevent a *direct* application of the metabolic rates of living reptiles and amphibians to some of their more famous ancient forerunners, although there are likely certain characteristic similarities.

11. For example, the difference, especially in terms of geochemical energy, between two different species of mice is much less significant than the difference between a mouse (representing the mammalian class) and a lizard (representing the reptilian class). The standard taxonomic order, from low to high, is: species, genus (plural genera), family, order, class, phylum, kingdom.

The common amphibians of today are different from those dominant forms of seemingly amphibian-like vertebrates of 300 million years ago. The ones we find today did not exist then, and the skeletons of those we dig up from millions of years ago do not exist now... at least not most of them.

There are curious cases, however, often referred to as "*living fossils*," which help provide a critical glimpse into the ancient past. These are identified as species which emerged in the distant past, and have remained for a long period of time, having changed little for millions of years. There are only a very few such species of any given group, and they are often found in remote locations, either having been isolated from the main mode of the biospheric animal system, or having found new, minor roles in new biospheric stages.

Figure 2



Generalized succession of dominant forms of vertebrates illustrated by the comparative number of known families over geological time. Examining the number of genera or species, instead of families, yields slightly different curves, but the same series of successions.

Image adapted from Michael Benton, "The history of life: large databases in palaeontology" in D. A. T. Harper (ed.), *Numerical Palaeobiology.* Wiley, Chichester, 1999, pp. 249-283.

For example, a handful of strange egg-laying species of mammals still inhabit regions of Australia and the surrounding islands. These are mammals of the *monotreme* order, and only two forms exist, the echidnas, of which there are only four species, and the platypus, with only one species. As of recent studies,[12] it is thought that the echidna and platypus have existed for over 110 million years, and that the currently living species are representatives of this distant time. Thus they are often referred to as "living fossils."

Another strange grouping of mammals separates itself, *marsupials*, distinguished by their pouches, used to raise their young, instead of the placenta of the more common *placental mammals* of the biosphere today.

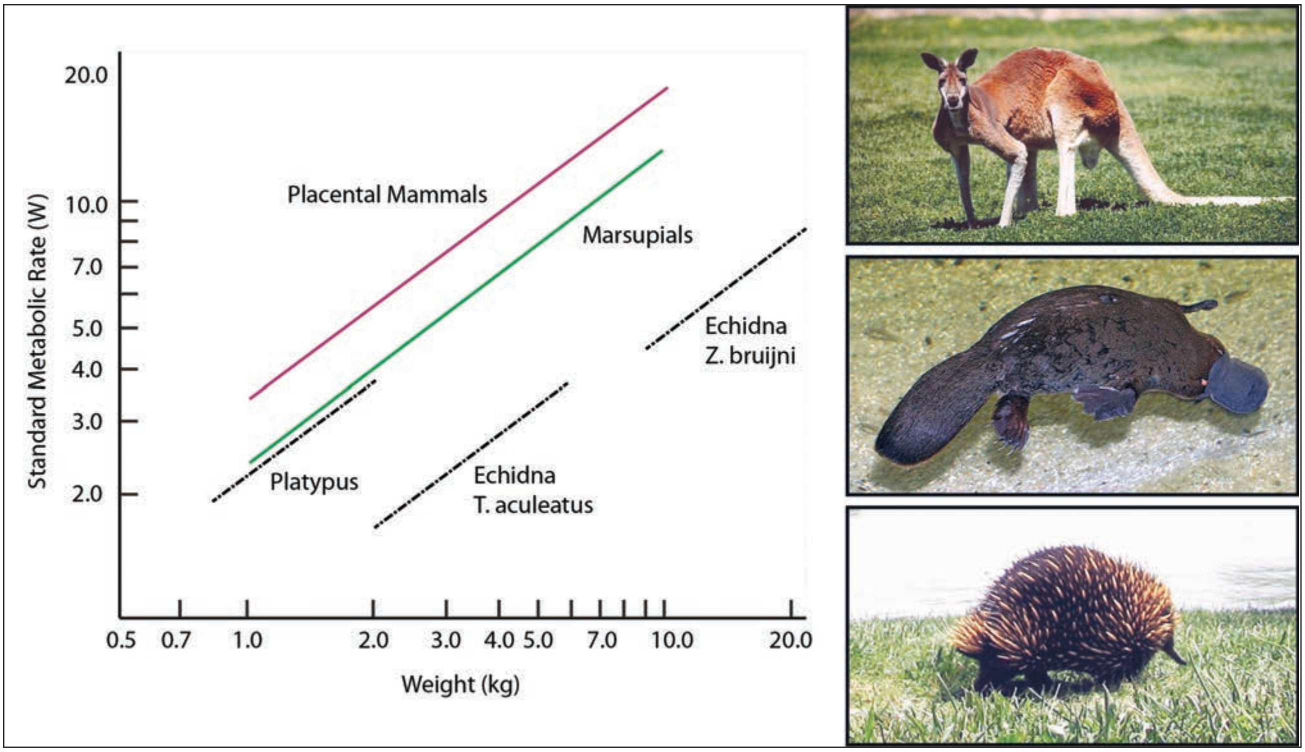
Monotremes, marsupials, and placental mammals comprise a set of three very distinct forms of mammals which show distinct energetic differences. All are warm-blooded, but some are more so than others. The monotremes have average body temperatures of only about 90°F. Marsupials maintain a higher average body temperature, around 95°F, which is still below the average body temperature of most placental mammals, about 99°F. These different body temperatures correspond to the same succession of different metabolic rates, as indicated in Figure 3.

This indicates that the placental mammals express a characteristically higher geochemical energy. Based on Vernadsky's concept of progress being expressed in increased biogenic migration of atoms, this may be viewed as a fundamental reason for the global dominance of placental mammals (with an estimated well over 5,000 species), the lower role of marsupials (with a little over 300 species), and the tucked-away handful of monotremes (5 species).

Currently the latter two groups are mostly found in and around Australia, largely isolated from the core placental mammal mode. But that was not always the case. For tens of millions of years, South America maintained a strong and diverse marsupial population, including many species appearing remarkably similar to certain placental mammal parallels (such as a marsupial version of the saber-toothed cat, for example). This diverse marsupial population of South America flourished, as long as it remained separated from North America, which was the case for

12. "Molecules, morphology, and ecology indicate a recent, amphibious ancestry for echidnas," Matthew J. Phillipsa, et. al., *PNAS*, October 6, 2009, vol. 106, no. 40.

Figure 3



A graph showing the average metabolic rates of placental mammals, marsupials, and three species of monotremes (a platypus and two echidna) compared on a logarithmic scale. Different from the metabolic comparison in Figure 1, this measures the total metabolic rate of the whole organism (as opposed to the metabolic rate per unit mass). Pictures (top to bottom) of a kangaroo (marsupial), a platypus (monotreme), and an echidna (monotreme).

Graph adapted from page 144 of *Comparative Physiology: Primitive Mammals*, by Knut Schmidt-Nielsen, Carla Liana Bolis, and Charles Richard Taylor; Cambridge University Press, 1980. Echidna picture from wikipedia user Skyring, platypus picture credit Stefan Kraft. The adapted image is licensed under Creative Commons Attribution-Share Alike 3.0 Unported

tens of millions of years. About three million years ago, a landbridge re-connected South and North America (the formation of the Isthmus of Panama) and for the first time, the placental species of the north moved into South America, largely overtaking and replacing the marsupial system with the higher-order placental mammal system, leading to the extinction of the vast majority of the South American marsupial system.[13] Although this also gave the southern marsupials a chance to migrate north, only a few species, such as the opossum, were able to integrate into the placental mammal system, but no extinction of placental mammals as a consequence of marsupial migration is recorded. The introduction of the placental mammals into a marsupial system had a completely different effect than the introduction of the marsupials into a mammalian system.

Today, the last small foothold of the marsupial system is on and around the isolated continent of Australia.

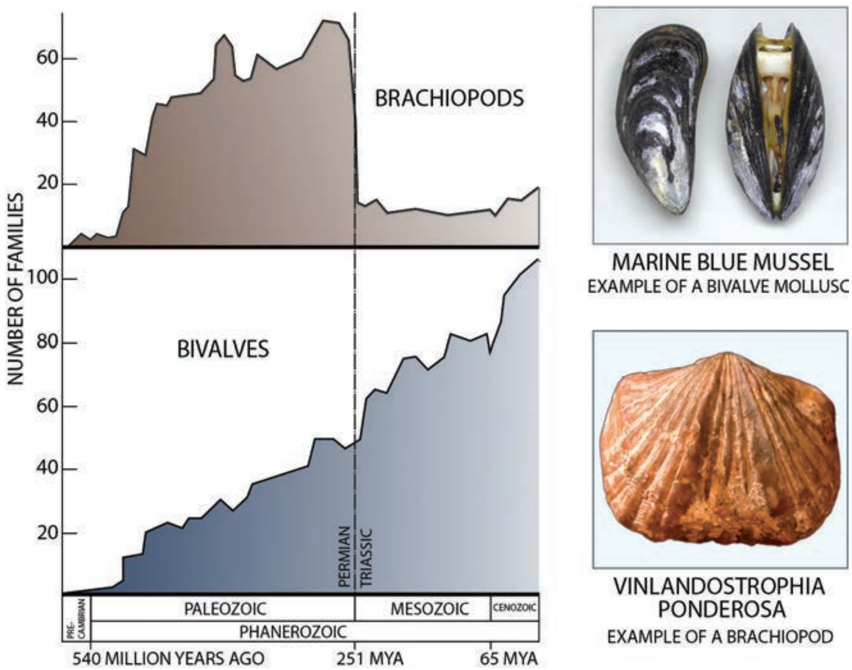
Marsupials aren't the only strange creatures tucked away in that corner of the planet. A second example is the creature known as the tuatara. Although looking like a lizard, the tuatara is actually a significantly different holdover from 200 million years ago (a time well before the modern lizards of today emerged). Currently there are only two living species, isolated to New Zealand and some surrounding islands. From the perspective of Vernadsky's geochemical energy, what stands out is the significantly lower metabolic rate, with average body temperatures half to a quarter that of comparable modern lizards. Keeping with the pattern of lower-energy systems being driven out by higher-energy systems, currently the tuatara species are being threatened because rats have be-

13. As one geologist who is an expert in the region stated quite frankly, "If the Isthmus of Panama [the landbridge] was not there, the world would be very different today. All the animals of South America would be unique marsupials, like in Australia, very different to today because they would never have been invaded and overtaken by all the species that colonized from North America." See "How the Isthmus of Panama Changed the World," April 13th, 2011, Smithsonian Journeys blog. (http://www.smithsonianjourneys.org/blog/2011/04/13/how-the-isthmus-of-panama-changed-the-world/)

gun to populate the islands, and are threatening to overtake the tuatara which had hidden in their lower-energy haven for tens of millions of years.[14]

One last specific example shifts the discussion from the Australian region of the planet to oceans all over the globe. For hundreds of millions of years, the ocean floors were populated with forms of two shelled creatures called brachiopods. They are actually the most common animal fossils found from the Paleozoic era,[15] due to both their abundance and the fact that they fossilize well. Despite the fact that they appear visually similar to clams, they are actually quite different, and separated by 600 million years of evolution.[16] Both these ancient brachiopods and our modern day clams (and their bivalve class) are filter feeders, constantly circulating volumes of water through their bodies and playing an important role in the biogeochemistry of ocean systems. The evolutionary transition from the domination of brachiopods to bivalves is a well-studied case in paleontology for a few reasons, but, specifically for the argument here, it expresses another example of increased geochemical energy of the biosphere. Tests on modern bivalves indicate nearly ten times the metabolic rate of modern brachiopods, translating to a higher rate of circulation of the ocean water, migration of chemical elements, transformation of material, etc., and they are more effective at filtering food from the water. In the paper, "Seafood Through Time," paleontologist Richard Bambach discusses how this is associated with bivalves having greater capabilities in the biosphere, and why the modern brachiopods are relegated to the outskirts of ocean floor communities where food supplies are low:

Figure 4



Comparison of brachiopods to bivalve molluscs over the past 540 million years in terms of the total number of families found at any one time.

"Clams and Brachiopods-Ships that Pass in the Night,*" 1980, by Stephen Jay Gould and C. Bradford Calloway; "Seafood through time: Changes in biomass, energetics, and productivity in the marine ecosystem," Richard Bambach; Paleobiology,* Vol. 19, No. 3, Summer 1993, pp. 372-397. Blue mussel photo from wikipedia user Rainer Zenz.

For example, Thayer (1981) called the sedentary, passive, suspension feeding articulate brachiopods "minimal organisms" and pointed out the variety of ways in which [brachiopods] function with low energy expenditure. In contrast… bivalve mollusks are more active. Many move around, even if sluggishly, some burrow actively, and some scallops can swim. The contrast extends to metabolic rates. Peck et al. (1989) reported that, for individuals of equivalent biomass under similar physical conditions, the oxygen consumption rate for the articulate brachiopod *Terebratulina retusa* (L.) is only 12% of that of the byssate bivalve *Mytilus edulis*. Thayer (1992) argues that the low energy requirements of articulate brachiopods accounts for their continued abundance in low food supply (oligotrophic) environments while bivalves dominate in more food-rich habitats.[17]

As expressed in the case of brachiopods versus bi-

14. Just recently, a New Zealand financier and rabid environmentalist, Gareth Morgan, has drawn international attention for promoting a campaign to eliminate all cats from New Zealand, including calls for possible mass euthanization of stray cats, because they are posing a threat to the native bird population of the island. The threatened birds include more unique holdovers, such as the New Zealand wattlebirds, of which there are only two remaining species, and likely stem from a split from other birds over 80 million years ago. New Zealand's famous oddity, the Kiwi, is also threatened by the mammalian invasion.

15. The Paleozoic era lasted from roughly 540–250 million years ago.

16. Clams (oysters, scallops, mussels, etc.) are part of the bivalve class of the mollusca phylum. Brachiopods makeup their own distinct phylum, based on fundamental structural differences.

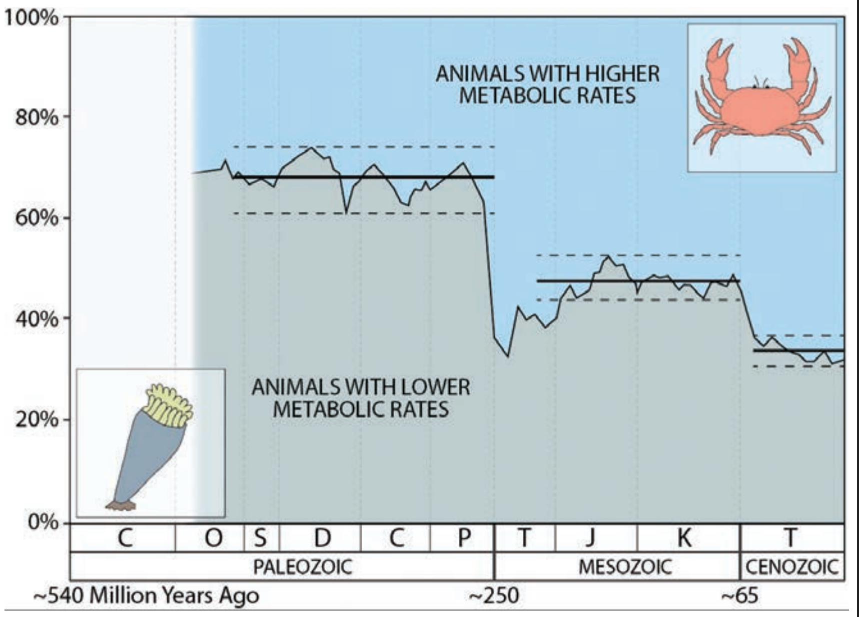
17 Richard Bambach, "Seafood through time: Changes in biomass, energetics, and productivity in the marine ecosystem," *Paleobiology*, Vol. 19, No. 3, Summer 1993, pp. 372-397.

valves, and in other examples above, the general trend has been the displacement of less-energetic forms of life with more energetic ones. For example, in the oceans today, the only places that forms of life which used to dominate in Paleozoic era continue to reign, are in low-energy regions, with lower food supplies or on the fringes of the more productive regions of the biosphere.[18]

The examples above have only focused on comparing specific groups. An indication of the changes in the metabolic activity of the *entire ocean system* is provided by a 2002 study, examining tens of thousands of living and extinct genera over the past 500 million years.[19] This takes the investigation of geochemical energy out of specific examples, and begins to approach the entire biosphere.

The study took a total number of 40,859 distinct ocean genera recorded in the geological record and divided them into two groups: those characterized by higher metabolic rates and those characterized by lower rates.[20] They then examined the changing ratio between these two groups over geologic time. The results would grab Vernadsky's attention at once.

Figure 5



The changing percentage of animal genera in the ocean with high versus low metabolic rates over time.

Image adapted from "Anatomical and ecological constraints on Phanerozoic animal diversity in the marine realm," by Richard Bambach, Andrew Knoll, and John Sepkoski, May 14, 2002; *PNAS*.

Two remarkable characteristics immediately jump out (see Figure 5). First, the relative stability of the biospheric system for many tens or even hundreds of millions of years: from about 445 to 250 million years ago, the division hovered around 70% of animals having lower metabolic rate, 30% higher. When a dramatic change occurred, ending this stage, the system re-stabilized at a new division of about 50 / 50. Approximately 65 million years ago, the last major shift brought the proportion of animals with lower metabolism to only about 35% and those with higher metabolism to 65%, thus nearly inverting the ratio from earlier conditions. At each stage, the values fluctuate around levels that are characteristic of that stage, suggesting that these levels are not accidental, but rather indicate a larger evolutionary structure of life, intimately tied to this concept of geochemical energy.

This analysis alone, examining the proportional structure of animal life in the oceans over time, provides very strong evidence for Vernadsky's second biogeochemical principle, illustrating progressive shifts in the internal ordering of the biosphere over time.

> The evolution of species, leading to the creation of new stable, living forms, must move in the direction of an increasing of the biogenic migration of atoms in the biosphere.

This is life's increasing power to *change* the environment, doing so at successively higher rates. With each advancement, the lower order systems, such as the marsupials, dinosaurs, etc., are either discarded and replaced, or subsumed and transformed by the progression of life to a

18 "Seafood Through Time," Bambach, op. cit.

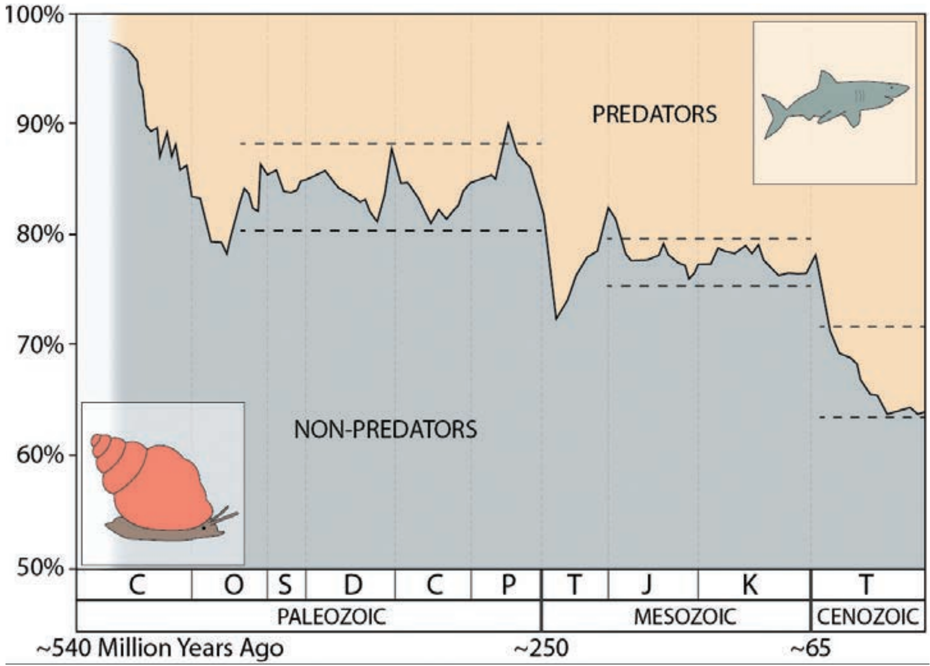
19 See Richard Bambach, Andrew Knoll, and John Sepkoski; "Anatomical and ecological constraints on Phanerozoic animal diversity in the marine realm," May 14, 2002; *PNAS*. Generally the fossil records from ocean life are more complete than comparable records of life on land, due to the better chances for organisms to be covered with sediment and preserved at the bottom of the ocean. This makes the marine fossil record a better subject for certain types of quantitative and qualitative analysis.

20 Their exact classification was slightly more complicated, but included the consideration of metabolic rates, which is being emphasized here. This was just one aspect of their study. See, Richard Bambach, Andrew Knoll, and John Sepkoski; "Anatomical and ecological constraints on Phanerozoic animal diversity in the marine realm," May 14, 2002; *PNAS*.

higher-order state.[21] Interestingly, a structure begins to emerge over the entire Phanerozoic eon, subsuming any one of the specific examples investigated so far. For example, the succession from the age of the amphibians, to the age of the reptiles, to the age of the mammals, defines the same three stages of activity as the changes in the percentage of ocean animals with higher metabolic rates.

This pattern continues to emerge when other examples of the increasing energy of the biosphere are examined.

Figure 6



The changing percentage of animal genera in the ocean which are predators.

Image adapted from, "Anatomical and ecological constraints on Phanerozoic animal diversity in the marine realm," by Richard Bambach, Andrew Knoll, and John Sepkoski; May 14, 2002; *PNAS*.

The Case of Predation

Broadening the investigation beyond metabolic rates alone, other proxies indicate the dominance of Vernadsky's second biogeochemical principle.

For example, certain modes of life simply require more energy to maintain, such as predation. Whereas many ocean animals, especially of more ancient times, could survive by simply consuming organic matter from the seafloor, or by filtering food out of the ocean water as it flowed by, the action of actively pursuing another animal requires a more energetic mode of life. This is associated with higher metabolic requirements, but also an expanding food supply, technological developments, and a more energy-dense food web (higher biospheric capital intensity) to support higher level predators.[22]

When the fossil record is examined, it is revealed that over evolutionary time, predation has increased. This can be seen most clearly by taking the percentage of predator genera versus non-predator genera of the total known fossil population at any given time. Remarkably, although slightly less well-defined, the same general stages emerge as in the comparison of metabolic rates above. While there is some less-regular change between 540 to 445 million years ago, a roughly 200 million year period of relative stability occurs, in which the ratio fluctuates above and below the level of about 15% predators, 85% non-predators. This period if followed by a dramatic shift approximately 250 million years ago, again followed by a period of recovery, stabilizing around the level of about 23% predators, 77% non-predators, with some fluctuation above and below. The last major shift, although not appearing quite as clearly as in the previous analysis of this type, begins at about 65 million years ago, taking a bit longer to settle, but arriving at a level of about 35% predators, 65% non-predators.

These three levels of predation again indicate three successive stages of energy-flux density in the biosphere. So far, this investigation has generally focused on Vernadsky's second type of biogenic migration of atoms, the rate or intensity *directly due to organisms' consumption, respiration, etc*. Vernadsky's third type, the biogenic migration *due to technological developments*, also clearly expresses this development.

21 For example, numerous species of amphibians exist today, but the vast majority of the species are very different from those that existed 400 million years ago, and the role of today's amphibians in the mammalian stage is fundamentally different than their role in the amphibian stage.

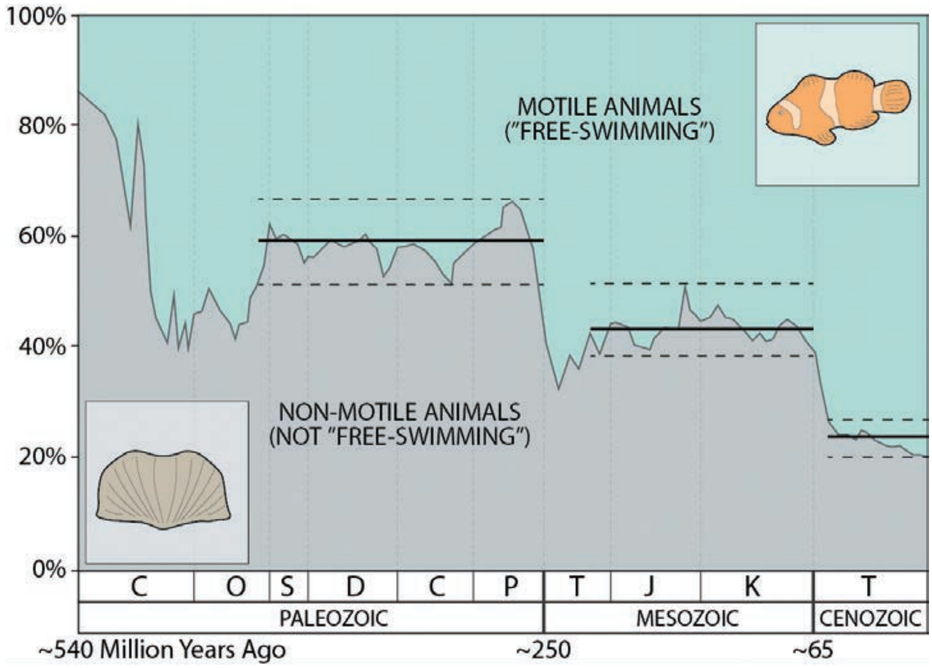
22 See, for example, the 1993 paper by paleontologist Richard Bambach, "Seafood through time: Changes in biomass, energetics, and productivity in the marine ecosystem," *Paleobiology*, Vol. 19, No. 3, Summer 1993, pp 372-397. Bambach offers a series of arguments that are extremely valuable, and provide more conclusive evidence when viewed from the perspective of Vernadsky's concept of evolutionary progress. Examining an array of innovative proxies, Bambach presents a clear case for the increase of the total energy and energy density of life in the oceans over the past 500 million years. Predation is one example he focuses on. See "Seafood Through Time," Bambach, op. cit.

Biogenic Migration of the Third Type

A new series of proxies provide information about Vernadsky's third type of biogenic migration, which he defined as:

> The migration of atoms, also sustained by organisms, but which is not genetically or immediately related to the penetration or to the passage of atoms through their body. This migration is provoked by technological activity. It is, for example, determined by the work of burrowing animals, of which we notice traces since the most ancient geological epochs, by the consequences of the social life of building animals, termites, ants, and beavers.

Figure 7



The changing percentage of animal genera that can freely swim and move around the ocean, compared with the percentage that are either stuck in one place, or which simply float with the ocean currents.

Image adapted from, "Anatomical and ecological constraints on Phanerozoic animal diversity in the marine realm," by Richard Bambach, Andrew Knoll, and John Sepkoski; May 14, 2002; *PNAS.*

This is expressed in a number of distinct ways. For instance, life has expanded into domains in which it did not exist prior, expanding the reach of the entire biogenic migration of atoms. Vernadsky gives the example of the development of birds, which now act as transporters of phosphorus and other chemical elements across the vast distances of their regular migrations. The movement of life onto land is another example, and perhaps the clearest: bringing the entire system of the biosphere to conquer and transform this new territory.[23] There are many useful examples within the ocean system as well.

On the ocean floors, the continental shelf area is generally the most populated with animal life. This includes animals which dig and burrow into the sediment of these shelf regions. The degree to which digging and burrowing animals have actively displaced and churned up the sea floor has increased over time. Going back to 540 million years ago, the records show that the average depth of life's displacement of the shelf floor was about 2-3 cm, with some sediments showing deeper, and others showing no disturbance. By 400 million years ago, 5-6 cm became average (again with some locations deeper and other locations with little or no disturbance). By 200 million years ago it became nearly impossible to find *any* layers of sediment, even as thin as 3-4 cm, that had not been disrupted by the activity of life. Starting about 65 million years ago, the activity has increased so much that certain forms of species that used to live by anchoring themselves in the sediment in earlier periods, could no longer live on the modern seafloor because the sediment was churned up and displaced at such a high rate they would be rapidly overturned, or even buried.[24] As Bambach stated in "Seafood Through Time:"

> Sediment disturbance by "biological bulldozers" (Thayer 1979) is now so severe that LaBarbara (1981) concluded that some reclining free-living bivalves which were abundant in the later Mesozoic, such as *Gryphaea* and *Exogyra*, would not be able to survive on the modern sea floor.

Thus, even something as simple as the ability of ani-

23 For example, the LaRouche PAC video, *The Hypersea Platform* (2011) presents the theory of the Hypersea, as developed by scientists Dianna and Mark McMenamin. http://larouchepac.com/hypersea-2011

24 "Seafood Through Time," Bambach, op. cit.

mals to move around freely has significant effects on the biosphere, expressing Vernadsky's third type of biogenic migration. To look again at the internal division within the biosphere, a similar comparison can be made between motile ocean animals that have the ability to swim freely around the ocean, and thus have the potential to participate actively in Vernadsky's third form of biogenic migration, versus those non-motile animals that do not, and are either stuck to one location, or simply float with ocean currents. Once more, the same pattern emerges when comparing the percentage of genera in the two categories:

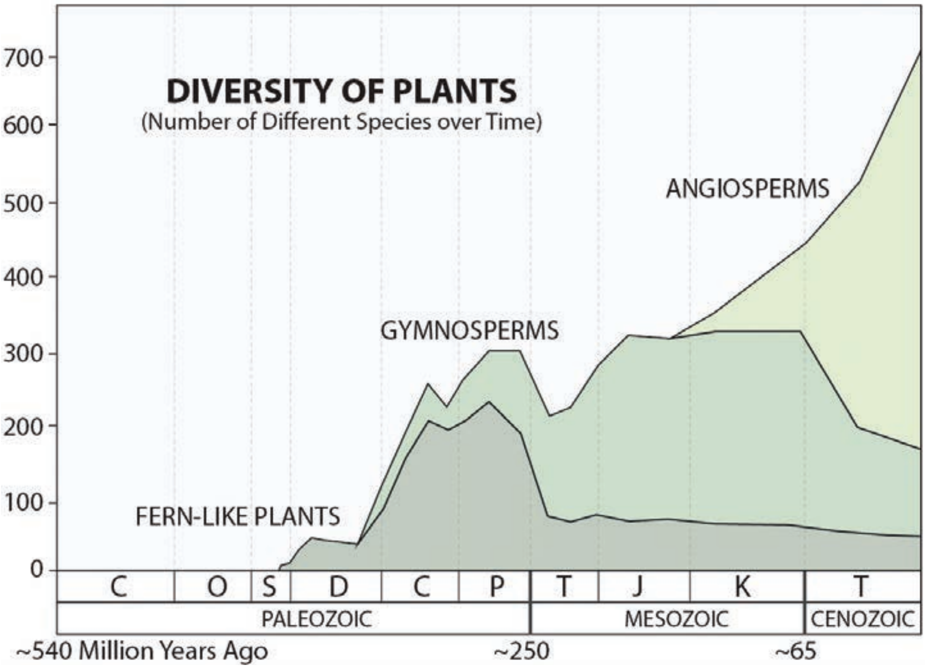
- Some irregularity from 540 to about 445 million years ago.
- Beginning at around 445 million years ago, there is a distinct 200 million year time period when the ratio of self-moving to passive life fluctuates slightly above and below the average level of about 40% to 60%.
- About 250 million years ago, this changes and recovers to a new stabilized level of about 55% to 45%, with fluctuation above and below this average.
- The last major shift beginning about 65 million years ago resulted in a new proportion of the ocean animal system, with almost 80% now being motile, and 20% not.

These proxies taken together—the increase in metabolic activity, increasing percentage of predator species, greater expansion of animal life into new regions of the biosphere, the greater displacement of material of the biosphere, etc.—all indicate the general increase in the biogenic migration of atoms through the biosphere over time. Vernadsky's second biogeochemical principle is confirmed in each of his three forms of biogenic migration.

These studies, however, have only treated *animal* life thus far.

Because animal life depends upon the action of photosynthetic life, as well as other key components of the biosphere, the increase of the biogenic migration of the animal system should parallel changes in the photosynthetic activity and other characteristics of the biosphere as well.

Figure 8



The biodiversity, counted in the number of different species, of three successive modes of plants, the pteridophytes (fern-like plants with spores instead of seeds), gymnosperms (with seeds but no flowers or fruit), and the angiosperms (flowering plants).

Adapted from, Niklas, Karl J. 1986. "Large-Scale Changes in Animal and Plant Terrestrial Communities." Pages 383-405 in D. M. Raup and D. Jablonski, eds., *Patterns and Processes in the History of Life*. New York: Springer-Verlag.

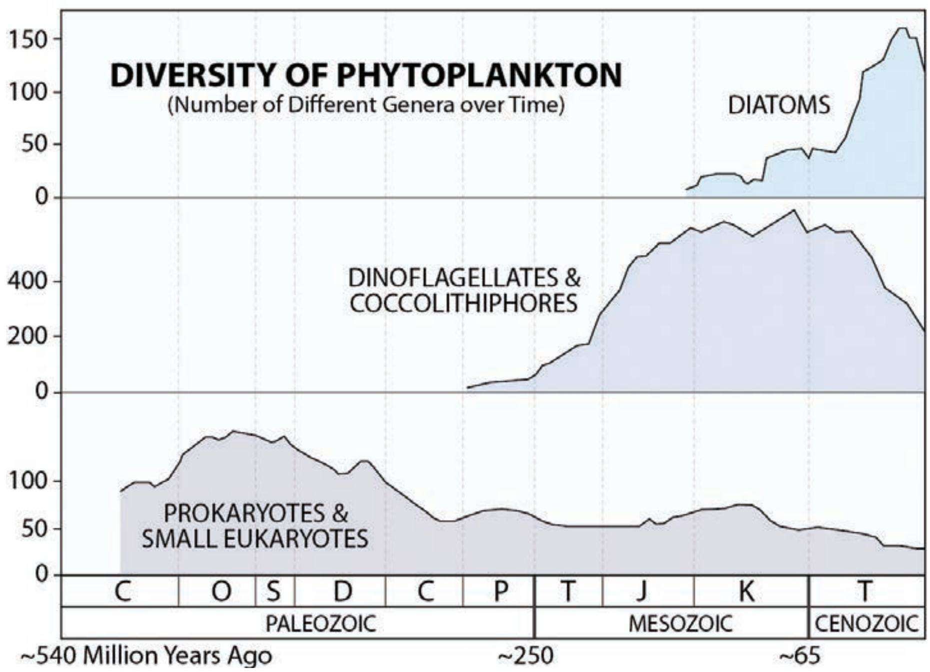
Kingdoms United

Much has already been written about the significance of the motion of plant life onto land: bringing the water cycle onto land in a completely new way, transforming weathering and related activity; plants driving the transformation of rocky lands to nutrient rich soils; all of this activity feeding back into the oceans, providing nutrients and helping upgrade the ocean system as well.[25] The full significance of this process from the standpoint of Vernadsky's three forms of biogenic migration of atoms requires an entire study in itself.

Once firmly rooted on land, clear shifts in the dominant forms of plant life are apparent. The first mode is characterized by the initial domination of fern-like plants, which have spores rather than seeds, requiring wet or moist environments in order to reproduce. Approximately 250 million years ago, the first seed-bearing plants, the gymnosperms, which had emerged earlier as a minority, began to dominate. The development of the seed, with its

25 *The Hypersea Platform*, LaRouche PAC video, 2011, http://larouchepac.com/hypersea-2011.

Figure 9



The changing biodiversity of the different modes of phytoplankton, measured in number of genera over time.

Adapted from "Evolutionary trajectories and biogeochemical impacts of marine eukaryotic phytoplankton," by Miriam Katz, et al., *Annual Review of Ecology, Evolution, and Systematics*, vol 35, 2004.

self-contained nutrient supply and internal fertilization, allowed plants to penetrate into drier regions of the land, forever changing the interiors of the continents. A third shift brought about a stage that is clearly associated with the shift in animal life around 65 million years ago, with the growing dominance of the flowering and nutrient-rich fruit-bearing plants, an increased energy density of sustenance which became crucial for the higher metabolic requirements of the mammalian system. Grasses (also flowering plants) emerged at this time as well, fast growing and providing the possibility for large grazing mammals.

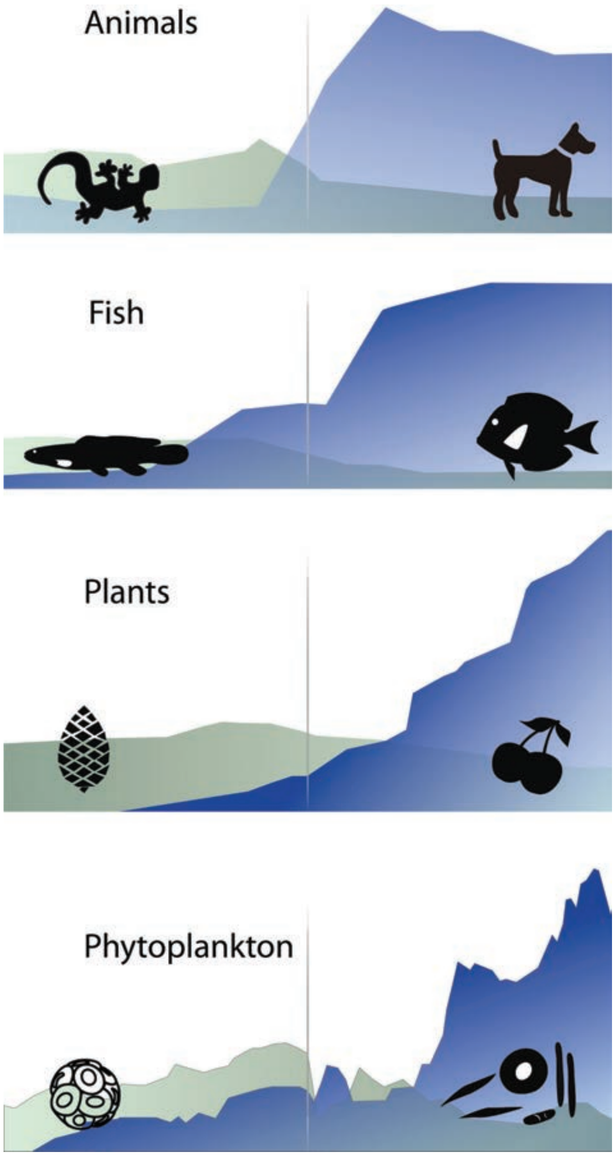
In the oceans, the majority of photosynthetic activity is provided not by multi-cellular plants, but rather by tiny single-celled creatures called *phytoplankton*. Even in this separate kingdom, there are parallel shifts around the same stages, with one set dominating from 500 to 250 million years ago, transitioning to new types which dominated from 250 to 65 million years ago, and a third type coming into dominance around the shift 65 million years ago.

Changes in the biochemistry of these sets of phytoplankton coincide with shifts in the broader food web they support. The phytoplankton of the first stage (including cyanobacteria and other prokaryotes) rely more on the trace metal nutrients iron, zinc, and copper, while the phytoplankton of the second and third stages require higher proportions of manganese, cobalt, and cadmium. Paralleling changes in capital-intensity in a growing human economy, the increased diversity seen in the phytoplankton realm was outstripped by the increasing development in the animal world they support. The first group (the prokaryotes) could support around five species per single species of phytoplankton, while the second (dinoflagellates and coccolithophores) supported around 10, and the third (the diatoms) supported 60.

The phytoplankton introduced with the third stage, the *diatoms*, also uniquely brought silicon into the biogeochemical cycles of the oceans in a completely new way. Even more interesting, this directly paralleled the development of grasses, which were the first land plants to require silicon in significant quantities, and played a crucial role in converting silicon into a soluble form, and helped to deliver it in a usable form into the oceans, much to the joy of the diatoms. Together, this brought the silicon cycle under the control of the biosphere to a degree never before achieved. Diatoms had other technological developments which helped them achieve a new space in the biosphere: they acquired a better control over their nitrogen and carbon usage by developing a urea cycle. They also developed a unique storage vacuole that could hold excess nutrients, allowing a diatom to go through several divisions without needing external supplies. There is little doubt about the significance of the change in the photosynthetic baseline in the oceans for the entire animal system which depends upon it. As one scientist put it, "the [expansion] of the diatoms in the Cenozoic era demarcates a large change in the food-web structure of the Phanerozoic oceans."[26] As is clear from

26 The Cenozoic Era spans from about 65 million years ago to the present day, and the Phanerozoic Eon spans from the Cambrian explosion of about 540 million years ago to today. See, "Evolutionary trajectories and biogeochemical impacts of marine eukaryotic phytoplankton," by Miriam Katz, et al., *Annual Review of Ecology, Evolution, and Systematics*, vol 35, 2004.

Figure 10



General biodiversity structure for different forms of life across the K-T extinction (marked here as the vertical line). Fish, tetrapods, land plants, and ocean phytoplankton (expressing the bounding top and bottom levels of the trophic system) all show the same character: the higher energy system starts in the second stage, grows in biodiversity, is less affected by the K-T extinction, and then comes into dominance. The lower order system is selectively more impacted by, or around, the K-T extinction, and declines thereafter, taking up a subsumed role within the new system.

Jablonski, eds., *Patterns and Processes in the History of Life.* New York: Springer-Verlag.

the above investigation, the change is towards higher rates of activity.

One last remark must be made about an often forgotten contributor to the biosphere, fungi. In Vernadsky's terms of the biogenic migration of atoms, fungi have played a consistent and important role, breaking down formerly living matter into forms that can be used by other living organisms.

Some biological structures decay more slowly than others. For example, lignin, a major structural component of plants, is one of the slowest plant structures to decay. It is also extremely hard to digest, and even animals that consume plant material do not consume lignin as a source of energy. If lignin is not consumed, or not broken down in some other way, it will just remain in that form for extended periods of time, being of little or no use to the biosphere, delaying the further useful biogenic migration of the chemical elements of which it is composed.

It was fungi that developed the capability to break down lignin, freeing carbon and oxygen, and increasing the rate of their cycling through the biosphere. Corresponding to the three stages of the biosphere discussed above, the development of this capability of fungi to break down lignin is part of the second stage, and associated with the overall increase of the biogenic migration of atoms associated with that stage.[27] Interestingly, fungi also go through an important shift associated with the third stage, the development of mushrooms, which are fruiting bodies with a higher density of consumable energy, allowing fungi to contribute to an increased food supply to the biosphere. All of this is well understood in terms of Vernadsky's second biogeochemical principle: the increase of the biogenic migration of atoms.[28]

Biospheric Energy Flux Density

From these examples from the plant and fungal kingdoms, the correspondence of developments within these kingdoms with development of the animal system is clear. Taken together, these become various proxies of a single metric, the general *biospheric energy-flux density* of successive geological periods.

The turnover from the popularized age of the amphibians, to the age of the reptiles, to the age of the mammals, defines the same biospheric shifts as the three stag-

27 "Seafood Through Time," Bambach, op. cit.

28 Interestingly, this development actually requires a net input of energy by the fungi. While fungi gain energy by consuming other plant material, for them to break down lignin they must lose energy to do so. It is as if they are working to contribute to accelerate the rate of biogenic migration of the whole biosphere, and not only acting in their own self-interest.

es of divisions of changes in the proportions of high versus low metabolic rates in the oceans. These shifts correspond with changes in other distinct sections of the biosphere: in photosynthetic life (both on land and in the oceans), in the percentage of species which are predators, in the ratio of animals which can freely move about the oceans, in the developments in fungal life, etc. These are all expressions of an overall increase in the

Toward A Physical Science of Anti-Entropic Evolution

For the large-scale development of the biosphere, the principle of progress is expressed clearly. From this understanding, the science of the anti-entropic system of the biosphere can be further refined, especially as mankind continues to dominate, manage, and increase the productivity of the biosphere, by applying the higher order creative power of mankind.

Addressing outstanding questions and challenges would further Vernadsky's hypothesis of the nature of the progress and development of the biosphere over time. This could provide a better understanding of the history of life, but also of how mankind can better manage and improve the biosphere (and also, eventually create a new biosphere on another planetary body). Such challenges include:

1. Refine possible metrics for biospheric energy-flux density. Something that can more specifically measured and/or estimated for both previous periods, and for current and future times.

2. Map the changes in the biogenic migration of atoms over the evolutionary development of the biosphere from the standpoint of the entire periodic table. How does the role of each chemical element evolve and change?[1] What about each isotope? How do the cycles and rates of key constituent elements of life, such as carbon or oxygen, change? What about trace metals and micronutrients, such as cadmium and copper, or the expansion of which elements and isotopes are used, such as the case of silicon? What can be learned about the changes and expansion of the different biological or biogenic structures formed in the biosphere? This could lead to an entire new periodic table, perhaps, and even provide for a better understanding of the distribution of natural resource deposits, or even the possibility of creating them biologically.

3. Investigate more specifically how the increasing biospheric energy-flux density corresponds to technological developments in the morphological structure of living organisms. For example, the development of wings, or a self-regulated body temperature. Many of these technological innovations made it possible for living organisms to expand into new regions which were simply out of prior reach.[2]

4. Develop a new taxonomic classification system from the standpoint of the process of the evolutionary development of the biosphere. As Vernadsky emphasized, solely defining the organism by its appearance is an abstraction. Instead, it must be investigated from the standpoint of its contribution to the entire process of the biosphere, and the evolutionary development of the biosphere over time.

5. Map out the times when living organisms fundamentally changed the material-energetic state of sections of the biosphere or lithosphere, making previously uninhabitable regions, habitable—the biospheric equivalent of infrastructure. Certain well-known case studies stand out, such as the motion of life onto land, or the oxygen revolution, but there may also be more subtle changes in the biogeochemistry or energetic conditions of the biosphere which have paved the way for new forms of life. For example, perhaps this could be seen in shifts in the utilization of the elements of the periodic table by the biosphere over time.

6. A study of the historical emergence and expansion of the noösphere in controlling and augmenting the biosphere. Recent studies have indicated that mankind's role is much stronger farther back in time than popular opinion has admitted thus far. Take, for example, the recent revelation that even the current nature of the Amazon rainforest is the product of mankind's activity going back thousands of years.[3] Plant and animal husbandry has gone back much farther. Irrigation systems have transformed deserts; fertilization has transformed soils. In terms of energy-flux density, productivity, and biogenic migration, what has this process looked like from the earliest times up to today, and how will we shape it into the future?

1. In his speech on evolution, Vernadsky gives a few examples, such as the changing role of calcium, or phosphorus. Meghan Rouillard discussed the dramatic changes in the biogenic migration of silicon in her video production, *Single-Celled Creativity*, http://larouchepac.com/node/17850

2. For example, in 1985 Richard Bambach produced an excellent analysis of most of the phyla and classes of the ocean fossil record over the past 540 million years, identifying specific technological shifts in the morphology of various species which were directly associated with the expansion of the biodiversity of that group. See, "Classes and adaptive variety: The ecological diversification in marine faunas through the Phanerozoic," by Richard Bambach, published in the book, *Phanerozoic Diversity Patterns*, 1985, Princeton University Press, edited by James Valentine.

3. See "Virginity Lost" by Fred Pearce, in the January-March, 2007, issue of *Conservation*.

biospheric energy-flux density of the entire system of life on Earth.

Provocatively, these transitions from one stage to the next are demarcated by the largest mass extinctions of the entire Phanerozoic eon (the last 540 million years). The initiation of the first stage is marked by the Ordovician-Silurian mass extinction of 445 million years ago, the second largest mass extinction of the eon. The division between the first stage and the second (250 million years ago) is provided by the largest mass extinction of the eon, the Permian-Triassic mass extinction, and the shift from the second to the third stage is demarcated by the famous K-T mass extinction which eliminated the dinosaurs, and approximately 75% of all species on the planet, about 65 million years ago.

Even more interesting, each of these extinctions is selective with respect to the organisms associated with the respective stages of biospheric energy-flux density. The biodiversity of the diatoms was hardly affected by the K-T mass extinction, whereas the phytoplankton of the second stage were much more severely hit, and never regained the diversity they had prior. Although mammals were affected, the K-T extinction was much more devastating to the reptilian class. The case is similar for angiosperms compared with gymnosperms, etc. (see Figure 10). The same character of energy-flux density selective extinction is clear in the transition from the first stage to the second, as seen in the comparisons of bivalves and brachiopods, reptiles and amphibians, fern-like plants and gymnosperms, etc. This is also reflected in each of the three charts showing the increasing percentages of animals with higher metabolism, which are predators, and are freely-moving, with each shift occurring at these mass extinctions.

Understood in this context, the traditional view of the mass extinction needs to be inverted. Instead of a self-defined event, interrupting some balance of life, the mass extinctions become merely shadows or effects of a primary process of anti-entropic growth in the biosphere. While there may have been particular triggers, such as an asteroid impact, which might have helped to affect the exact timing, or kick-start a transition, they are of secondary importance, and not the *cause* of the anti-entropic development of the biosphere.

As Vernadsky said,

> Taken together, the annals of paleontology do not show the character of a chaotic upheaval, sometimes in one direction, sometimes in another, but of phenomena, for which the development is carried out in a determined manner, always in the same direction, in that of the increasing of consciousness, of thought, and of the creation of forms augmenting the action of life on the ambient environment.

These three stages of the development of life characterize the development of the biosphere in broad, but crucial strokes (see the table, *Three Stages of the Phanerozoic Biosphere*, in the appendix). Although much more work must be done to bring the investigation to greater resolution (see box), this should stand as undeniable proof of Vernadsky's great second principle of biogeochemistry, a principle of progress.

Willfully Acting on Principle

What does all of this mean for mankind today? Is mankind destined to be just another animal species, overtaken by the evolutionary process of the biosphere? Or perhaps by changes and developments in our Solar System, or even within our galaxy, which continue to have direct impact on the conditions of life here on Earth? This points to a more fundamental issue.

Progress is a principle of the universe in which we live. We certainly do not know the universe in its entirety, but we can know and understand this characteristic. Forms of existence that do not progress go extinct. Progress, per se, is not a vague, indefinable notion, but has a very specific character. For human society, this is expressed by a power that is completely absent from any form of animal life alone. It is the unique potential to act *willfully*, to creative new stages of nature, states which never before existed, and would be impossible for simply life, unaided by human creative action, to ever generate—in short, to willfully act in, and create our own future.

As Vernadsky recognized, this raises interesting questions. The action of human society can be seen in the unique quantitative and qualitative increase in the biogenic migration of atoms as a consequence of human activity.

> The role of civilized humanity, from the point of view of the biogenic migration of atoms, was infinitely more important than that played by the other vertebrates. Here, for the first time in the history of the Earth, the biogenic migration due to the development of the action of technology was able to have a greater significance than the biogenic migration determined by the mass of living matter.
>
> At the same time, the biogenic migrations changed for all of the elements. The process was rapidly effected in a relatively insignificant amount of time. The face of the Earth transformed itself in an unrecognizable way, and yet, it is clear that the era of this transformation has only just begun.
>
> These transformations conform to the data of the second biogeochemical principle; the change led to an extreme growth of the intensity of the biogenic migration of atoms in the biosphere.
>
> It is necessary to note here two phenomena: Firstly,

Man (and this can not be doubted) is born of an evolution, and secondly, in observing the change which he produces in the biogenic migration of atoms, we note that *it is a change of a new kind, which, with time, accelerates with an extraordinary rapidity.*[29]

These changes in biogenic migration, while completely unique to only human action, can be measured in terms of certain material and energetic effects—the migration and transformation of chemical elements as a function of human activity. However, the actual source of these changes can not be measured in terms of matter or energy. The power of human creativity, is not, itself, measured in material or energy terms, or even in simply biological terms. The changes mankind induces in the material-energetic state of the biosphere or lithosphere exist as a shadow, as a mere expression of a capability, a power, which uniquely lies with the human mind.

It seems that this study opens before us yet another domain of the phenomena of scientific activity, until now exclusively reserved to the speculations of philosophy or religion.

The new form of biogenic migration, at least new to this scale, was provoked, as we see, by the intervention of human reason.

However, it does not dis-

29 Emphasis added.

Figure 11

The North American Water and Power Alliance, NAWAPA, would save massive amounts of freshwater from otherwise wastefully running off into the northern Pacific and Arctic oceans, by directing it down through a series of natural trenches, rivers, tunnels, canals, and reservoirs, into the western United States and northern Mexico.

For more see, http://larouchepac.com/nawapaxxi tinguish itself in any of the other manifestations of biogenic migration, which are connected to other vital functions.

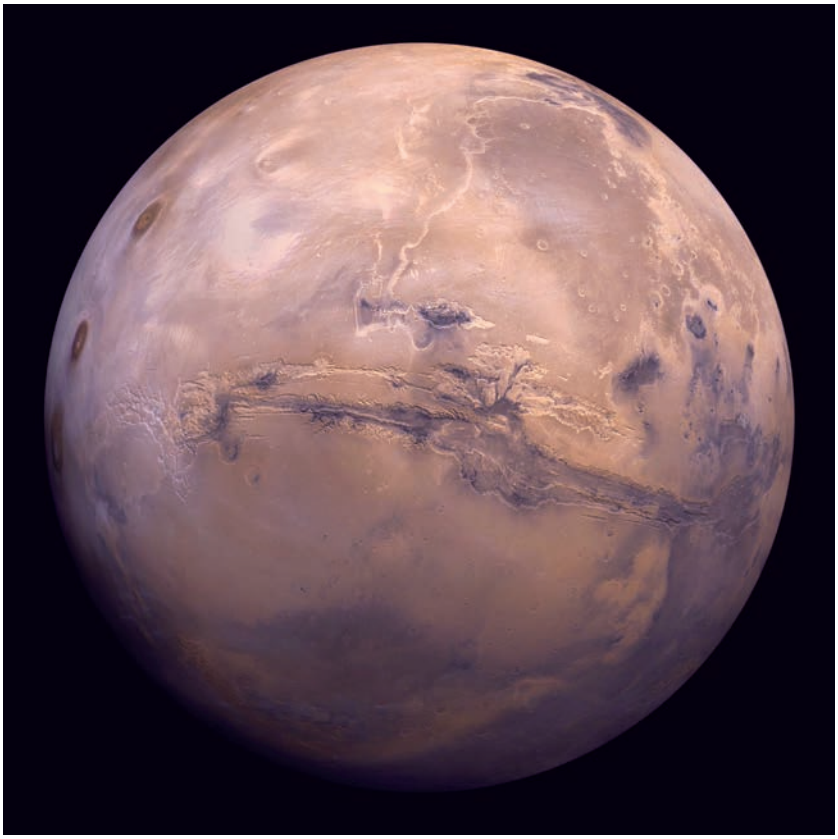
We can, at the same time, establish in a precise way, that human thought changes in a sharp and radical way the course of natural processes, and modifies that which we call the laws of nature.

Consciousness, and thought, despite the efforts of generations of thinkers and wise men, cannot be reduced to either energy or matter, however we define these bases of our scientific thought.

How can consciousness act on the work of natural processes which seem to be entirely reducible to energy and matter?

It is probable that we will not be able to resolve this question until after having radically changed our fundamental physical notions, notions which have undergone and still undergo transformations with a rapidity for which we know of no prior examples in the history of thought.

Figure 12



Mars represents, for mankind, a challenge even more important than Columbus' crossing of the Atlantic Ocean.

Credit: U.S. Geological Survey

Thus, the continual demand for progress for mankind takes a fundamentally different form. It is the continual expansion of the creative powers of society, measured in terms of the power of scientific and cultural thought to act upon and transform our planet at higher and higher rates. Society must always move in the direction of higher levels of energy-flux density in terms of physical economics, as measured in the forms of "fire" that can be wielded under the control of scientific thought: the general succession of burning biomass, to coal, petroleum, nuclear fission, thermonuclear fusion, and the prospect of matter-antimatter reactions, is exemplary.

This is coupled with the expansion of human management of more and more of the territory of the Earth. Programs such as the North American Water and Power Alliance (NAWAPA) are exemplary, designed to provide an integrated controlled water management system for much of the North American continent, shifting excess water to where it is needed, and dramatically transforming the biospheric productivity of much of the total land area. Water that is brought inland and participates in plant life is much more likely to evaporate and fall back down as rainfall multiple times before returning to the ocean. On average, plants increase this water usage 2.7 times, and more in heavily forested areas.

Despite the great lie of the environmentalist movement—which is an affront to the principle of life itself—continuous, never-ending progress is the only measure by which mankind can justifiably view his actions.

These challenges must be met with the goal of mastering the entire principle of the evolutionary development of the biosphere, and consciously wielding and applying that understanding for the betterment of the Earth itself, and eventually, other planetary bodies as well. Viewed from the perspective of an awaiting barren Mars, such discoveries are crucial, and there is too much progress demanded to waste time with stagnation.

This defines the necessary mission for the progress of mankind, one which would please Vernadsky in celebration of his 150th birthday.

Three Stages of the Phanerozoic Biosphere

	Stage 1: 445 to 250 MYA	Stage 2: 250 to 65 MYA	Stage 3: 65 MYA to Present
Photosynthesis: Ocean	Metabolic Rates / Energy Flux Density (EFD):	Metabolic Rates / EFD:	Metabolic Rates / EFD:
	Technology and Expansion:	**Technology and Expansion:** Cocolythophores and Dinoflagellates emerged as the first forms of eukaryotic phytoplankton to play a dominant role in the oceans.	**Technology and Expansion:** Diatoms developed a urea cycle, increasing more efficient utilization of nitrogen and carbon. They developed a storage vacuole, for storing nutrients.
	Biogenic Migration of Atoms: Cyanobacteria and other prokaryotic phytoplankton are of the green plastid lineage, requiring more iron, zinc, and copper.	**Biogenic Migration of Atoms:** Cocolythophores and dinoflagellates (and diatoms) are of the red plastid lineage, requiring more manganese, cobalt, and cadmium.	**Biogenic Migration of Atoms:** Diatoms made better use of nitrogen, and require silicon, bringing it under a tighter control by ocean life than ever before.
Photosynthesis: Land	**Metabolic Rates / EFD:**	**Metabolic Rates / EFD:**	**Metabolic Rates / EFD:** The energy densities of the fruits of angiosperms are better suited for the higher requirements of mammals, for example. Quick-growing grasses fed the development of grazing mammals.
	Technology and Expansion: Reproduction through spores. Vascular structures to bring water up for vertical growth. Roots to anchor into the ground.	**Technology and Expansion:** The seeds of gymnosperms allows for the penetration into dryer environments, no longer being dependent upon wet environments to reproduce.	**Technology and Expansion:** Angiosperm reproduction makes greater use of other animals as carriers of either fruit or pollen.
	Biogenic Migration of Atoms: …	**Biogenic Migration of Atoms: …**	**Biogenic Migration of Atoms:** Grasses require silicon, and have brought the silicon cycle under greater control on land than ever before.
Fungi	**Metabolic Rates / EFD:** Lignin-degrading fungi were rare or absent, leaving biological matter that resists decay for longer in the soils.	**Metabolic Rates / EFD:** The development of fungi with the ability to break down lignin significantly sped up the cycling of carbon and oxygen.	**Metabolic Rates / EFD:** Mushrooms make nutrients accessible to animals, and allow for more specialized spore-production.
Animals: Land	**Metabolic Rates / EFD:** Age of the amphibians.	**Metabolic Rates / EFD:** Age of the reptiles.	**Metabolic Rates / EFD:** Age of the mammals and birds.
	Technology and Expansion of Tetrapods: Moist skin and water-requiring reproductive strategies left amphibians tied to environments near the water.	**Technology and Expansion of Tetrapods:** Dry skin and eggs allowed for the expansion of reptiles into dryer environments.	**Technology and Expansion:** The warmblooded capabilities of birds and mammals allows for their expansion into colder environments.
Animals: Ocean	**Metabolic Rates / EFD:** Stage 1 division of high to low metabolic rates was ~30 / 70. Stage 1 division of predation was ~15 / 85. Shelf bioturbation increased, averaging 2-6 cm, with some regions untouched. "In general terms the Paleozoic dominants were low in individual biomass, their living tissue often arrayed as a thin two-dimensional film coating the skeleton..." (Bambach, 1993)	**Metabolic Rates / EFD:** Stage 2 division of high to low metabolic rates was ~50 / 50. Stage 2 division of predation was ~23 / 77, also associated with Vermij's "Mesozoic marine revolution". Shelf bioturbation increased to the degree that untouched sediments became very rare. "[the] replacement groups in the Mesozoic and Cenozoic and those added into the ecosystem are generally high biomass organisms, often with three dimensional masses of fleshy tissue" (Bambach, 1993)	**Metabolic Rates / EFD:** Stage 3 division of high to low metabolic rates was ~65 / 35. Stage 3 division of predation was ~35 / 65. Shelf bioturbation became so intense that immobile organisms living loosely planted in the sediments could not longer survive . "The energetics of many groups that dominate Cenozoic and modern faunas is greater that that characteristic of Paleozoic dominant groups" (Bambach, 1993)
	Technology and Expansion: Stage 1 percentage of free-swimming species was ~40%.	**Technology and Expansion:** Stage 2 percentage of free-swimming species was ~55%.	**Technology and Expansion:** Stage 3 percentage of free-swimming species was ~80%.