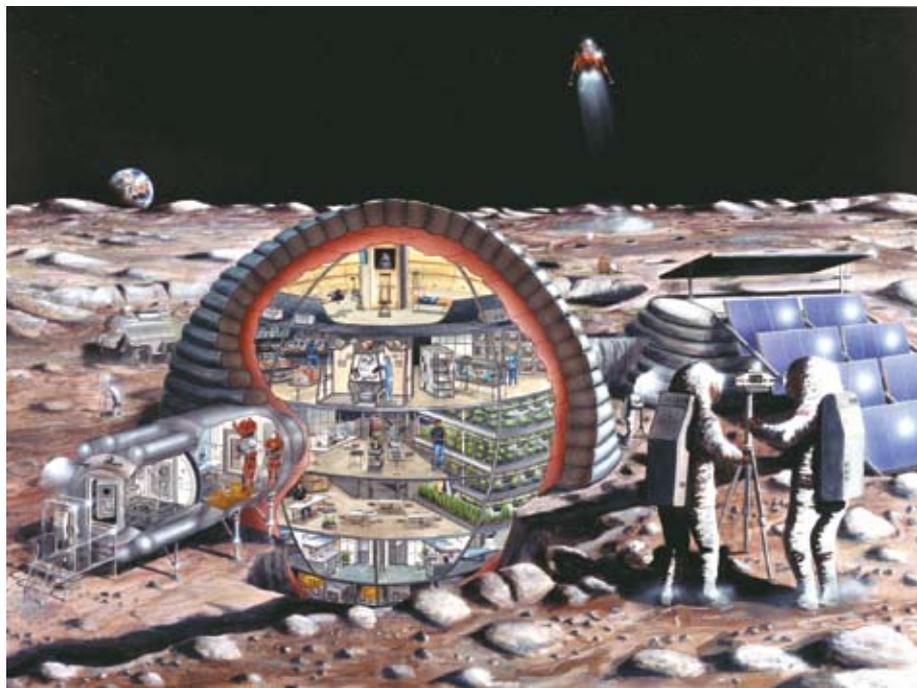


Isotopes and Life:



NASA

Creating a synthetic environment for man on another planet requires an examination of the role of isotopes and life. Here, an artist's conception of a small artificial habitat on the Moon.

Considerations for Space Colonization

by Meghan K. Rouillard

Since the beginning of the Twentieth Century, the proper modern understanding of the physical principles which underlie a competent science of physical economy, has been most clearly expressed in terms of that development of a specifically human practice of physical chemistry, as by such as, most notably, both Chicago's William Draper Harkins, and, in a more elaborated form, as premised on Academician V.I. Vernadsky's scientifically crucial elaboration of the notion of mankind's efficient role as a species in an anti-entropically developing universe. The latter development, that of Vernadsky, expresses the essential characteristic of a universe which subsumes the three sub-spatial domains of the lithosphere, biosphere, and noösphere.

—Lyndon LaRouche,
"The Secret Economy," *EIR*, May 28, 2010

The science-driver policy of colonizing space, which physical economist Lyndon LaRouche has declared to be the indispensable mission for advancing mankind, will require many fundamental scientific breakthroughs—indeed, a decisive break from the empiricist so-called science of today. The work of figuring out how to support man's creative activity away from the surface of the Earth—the creation of "synthetic environments"—actually requires a rethinking of the concept of basic economic infrastructure, as LaRouche has indicated.

In this paper, part of a series being produced by LaRouche's "Basement Team," we address the question of the nature of isotopes from the standpoint of the issues raised in creating an environment on another planet. Although the isotope question may appear complex to the lay reader, it is just this kind of knowledge which will determine the future of mankind.

Vladimir Vernadsky's concept of the three distinct phase-spaces of abiotic, biotic, and noëtic, was qualified by him on the basis of experimental phenomena, such as the different nature of the chemistry inside and outside of a living organism. Vernadsky pointed to the work of Louis Pasteur as crucial in this respect, regarding the significance of the symmetry of molecules with respect to certain biological functions.¹ Vernadsky made bold statements in 1938, and at other

1. LPACTV, "Louis Pasteur: The Space of Life," and Louis Pasteur, "On the Asymmetry of Naturally Occurring Organic Compounds," in *The Foundations of Stereochemistry*, (Woodstock, Ga.: American Book Co., 1901).

times, that there was a similar difference in the way in which isotopes are used inside and outside of a living process. He wrote:

Evidently, a shift (within certain ranges) in the isotopic composition (atomic weights) inside living organisms is a characteristic property of living matter. This has been proven for hydrogen, carbon, and potassium, and is probable for oxygen and nitrogen. This phenomenon calls for precise investigation. It is becoming more than probable, that a chemical element, upon entering a living organism, changes its isotopic composition.

“The chemical composition of both types of natural bodies comes down to the same chemical elements—although it is possible that the atomic weights of some or all of the elements are shifted in living matter.”²

Vernadsky was to be proven right in his hypothesis of a unique “fractionation” (the shifting of isotopic ratios from a given standard) of the latter two elements (oxygen and nitrogen) in living matter, which is documented in various studies. Interestingly, at the time Vernadsky first uttered such hypotheses, more than 10 years prior to the above-quoted statement, the heavier isotopes of several of these elements had not even been discovered. Vernadsky considered himself a rigorous experimentalist, but his hypothesis about the fundamental distinction between living and non-living matter drove much of that experimental



The Ukrainian-Russian biogeochemist Vladimir Vernadsky (1863-1945) conceived of the universe as composed of three distinct but interacting domains, which he called the abiotic, the biotic, and the nœtic.

work, and he encouraged others to pursue such tracks of investigation.

What are isotopes, such that life could use them “differently”? Or, inversely, what is life, such that it requires a unique isotopic composition? These questions are analogous to the question provoked by Pasteur’s work: What were the (at that time) hidden characteristics of what were thought to be similar molecules which caused life to distinguish between them? His work led to the science of stereochemistry, the study and significance of the orientation in space of molecules themselves.

What are the analogous hidden characteristics of isotopes which cause life to distinguish among them in a unique way, with respect to the environment in which the organism exists, or with respect to non-living matter?

What is life, such that it requires this? A pursuit of this question leads us in the direction of recognizing Vernadsky’s

point as being true: Life is a fundamentally unique state of physical space-time as compared to non-living phenomena. The particular ways in which isotopes interact with life are but one facet of this fundamental distinction.

We have reason to believe that fractionation would be caused

2. Vladimir Vernadsky, “Problems of Biogeochemistry II,” *21st Century*, Winter 2000-2001, p. 20.



The French chemist Louis Pasteur (1822-1895), often referred to by Vernadsky, was first to discover the handedness of molecules produced in yeast fermentation.

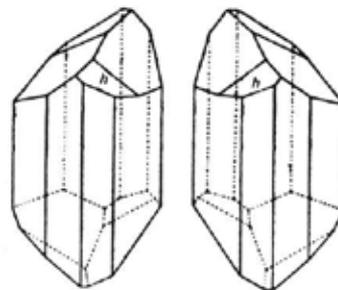


Figure 1

PASTEUR’S HANDED CRYSTALS OF TARTARIC ACID

Pasteur’s sketches of left- and right-handed crystals of tartaric acid, found in the bottom of wine barrels. When dissolved in solution, where the crystal structure would have been destroyed, the rotation of polarized light by the solution occurs to the right or left, depending on which crystalline structure was dissolved. This indicated to Pasteur that there must be handed symmetry, not only at the crystalline level, but also at the molecular level.

A living organism is selective about which of these handed molecules it uses, unlike non-living processes. Pasteur found that only the left-handed form is produced in biological processes, such as fermentation, while in laboratory synthesis of the compound, equal quantities of left- and right-handed forms occur.



NASA

Crew members of Shuttle Mission STS-040 in 1991 using an in-flight collection system to take blood for use in investigating the influence of space flight on red blood cells. Many questions remain about how living systems will react under the different isotopic composition of other planets.

by something other than the masses of the isotopes. This may sound surprising, based on the simple definition of what an isotope is, i.e., an atom of the same element which has a slightly different mass. Many simply “physical” processes could show “preference” for an isotope based on its mass. Size is one consideration in determining passive diffusion through a membrane, for example. This question can be answered based on simple physical laws, depending on the membrane.

But, based on Vernadsky’s view of Pasteur’s work, we have every reason to think that the space-time inside of a living organism is more unique, and perceptive, if you will, than what is implied by a simple apparatus to describe the laws of interaction between bodies and membranes. Part of what we intend to do here is to show that isotopes are, in fact, much more complex little creatures, which are not simply different because they are a little more or less hefty. And we would expect this to be the case, since a living organism is much more perceptive than a scale.



British physicist J.J. Thomson (1856-1940) experimenting with beams of positively charged neon ions in 1913, speculated that some neon ions might have different masses.

If life requires a unique isotopic composition, which is determined by a unique type of selection of isotopes within the organism, as hypothesized by Vernadsky, it would be a significant concern to be taken into account, in making plans to create artificial environments on our Moon or Mars, where isotopic composition is by no means certain to be the same as found on Earth, even where similar elements are to be found. Let us ex-

plore a bit of what we’ve come to know about that multi-faceted little creature, the isotope, and how life may be interacting uniquely with it. Though we may not arrive at any concrete answers, these questions are the ones we should be confronting and directing experimentation towards, in intending to leave the surface of our planet, to re-create human society on Mars.

It should also be said, that a true unified field theory should aim to define phenomena such as electromagnetism, gravitation, chemistry, and more, based on how these phenomena act in relation to each of Vernadsky’s three phase spaces.³The real prospect of space colonization makes this more than a simple academic pursuit, as we attempt to re-create an environment suitable for life on other planetary bodies. Knowing what isotopes “are” will require an experimental, but non-axiomatic study of how they interact with living matter. Those who have become acquainted with the mind of Vernadsky should concur that he would, most likely, be in agreement on this point. Let us begin by looking a bit at some of the initial paradoxes posed by isotopes, since their discovery.

The Shadows of the Isotope

In 1913, J.J. Thomson, in experimenting with beams of ions of the element neon (canal rays), deflected by electric and mag-

3. Sky Shields, “The Significance of Biological Research in Space for the Development of a Unified Field Theory,” Submission to the National Research Council’s Decadal Survey for Biological and Physical Sciences in Space, October 2009.

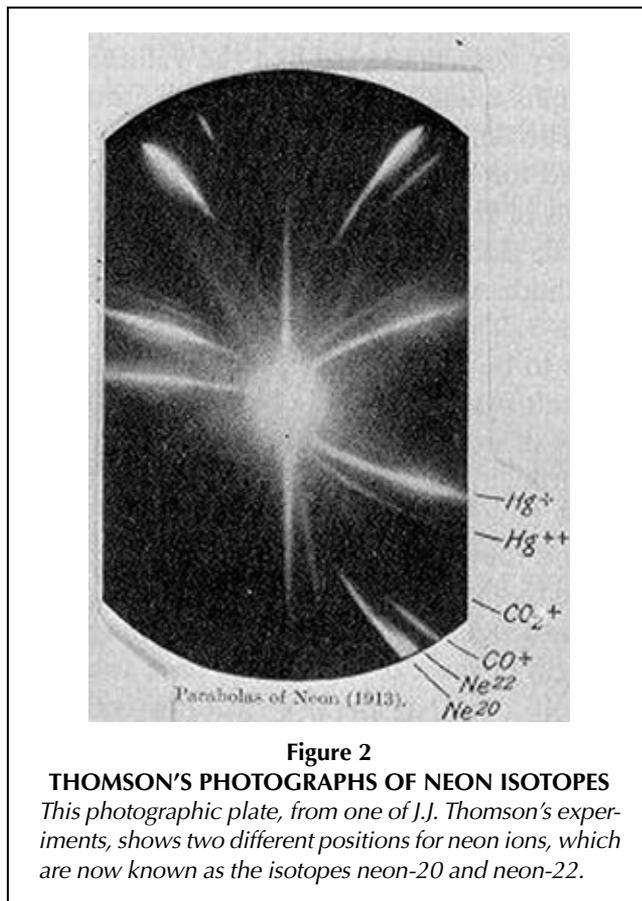


Figure 2

THOMSON’S PHOTOGRAPHS OF NEON ISOTOPES

This photographic plate, from one of J.J. Thomson’s experiments, shows two different positions for neon ions, which are now known as the isotopes neon-20 and neon-22.

netic fields, noted that some of these ions were deflected differently, having different parabolas of deflection, as seen by their projections on a photographic plate. This led him to think that these various neon ions, previously assumed to be all the same, could possibly have different masses.

In 1917, the Chicago University-based physical chemist William Draper Harkins began to investigate what were pointed to as being very slight differences in the spectra emitted from different isotopes of lead, and a few other elements. The differences were so slight, that, at the time, he was not even confident whether there was actually a difference. Without commenting on that investigation per se, we can gain some insight from his hypothesis, that there could be another characteristic to the isotope, besides a simple increase in mass, which would account for the different spectral emissions—something related to the different “space arrangement” itself.⁴

The fact that isotopes, with a constant value of P [protons], but with a variable value of b [neutrons], have almost exactly the same spectra, indicates that the non-nuclear electrons vibrate as might be expected, as if the positive and negative electrons [what he later was the first to call neutrons] were not present in the nucleus, that is as if it consisted of P positive electrons [protons] alone. . . . It might be expected, even if there is no effect due to the mass, that if the positive and negative electrons in the nucleus are not coincident, their space arrangement should cause a slight, though possibly unmeasurable effect upon the spectrum.⁵

So, Harkins figured that the simple mass increase contributed by uncharged neutrons would not change the spectral emission, but, a change in the orientation of the contents of the nucleus could. The usefulness of this statement is mainly that it introduces the idea that isotopes are not simply heavier or lighter, but that the change in structure itself could contribute to other kinds of differences, of the kind which would produce different emission spectra from different isotopes, for example.

This is not completely foreign to Pasteur’s own hypothesis that different molecules of tartaric acid could actually interact differently with a living organism because of their spatial arrangement, or their symmetry, not simply based on the “stuff”



University of Chicago physical chemist William Draper Harkins (1873-1951) did important experimental work on the structure of the atom, and was the first to demonstrate the slight differences in the spectra emitted from different isotopes.

4. Keep in mind, so as to make his statement more clear, that Harkins did not yet know of the neutron per se, but conceived of an atomic model which essentially did consist of neutrons, except that his neutrons were extra protons inside of the nucleus, orbited by electrons which cancelled out the charge of the protons.

5. William Draper Harkins, “The Spectra of Isotopes and the Vibration of Electrons in the Atom,” *Proceedings of the National Academy of Sciences of the USA (PNAS)*, Vol. 3, No. 12, Dec. 1917, pp. 710-715.

they are made of. Outside of the living organism, such differences do not matter. Vernadsky thought this implied a unique state of space of the living organism itself:

A chemical distinction between right- and left-handed forms of the same chemical compound, characterizes the state of the physical space, occupied by the body of a living organism, and its manifestation in the surrounding medium, in the biosphere.⁶

Perhaps we can not go so far as to claim to know what is being perceived by the organism, but symmetry seems to matter. This is an indication that life is different from non-life, even at the chemical level, which flies in the face of assertions that life could simply be built up out of the same “non-living chemicals.” There is, in fact, a difference when we discuss chemistry in the living organism. But what about at the even more relatively

microscopic level—at the level of the atoms which compose these symmetric molecules—isotopes? Vernadsky thought that this, too, was a phenomenon of a similar nature:

Don’t we have in this biogenic change of the atomic weight, one of the numerous manifestations of a sharp material and energetic distinction of the living matter and the inert, which are observed in all biogeochemical processes?⁷

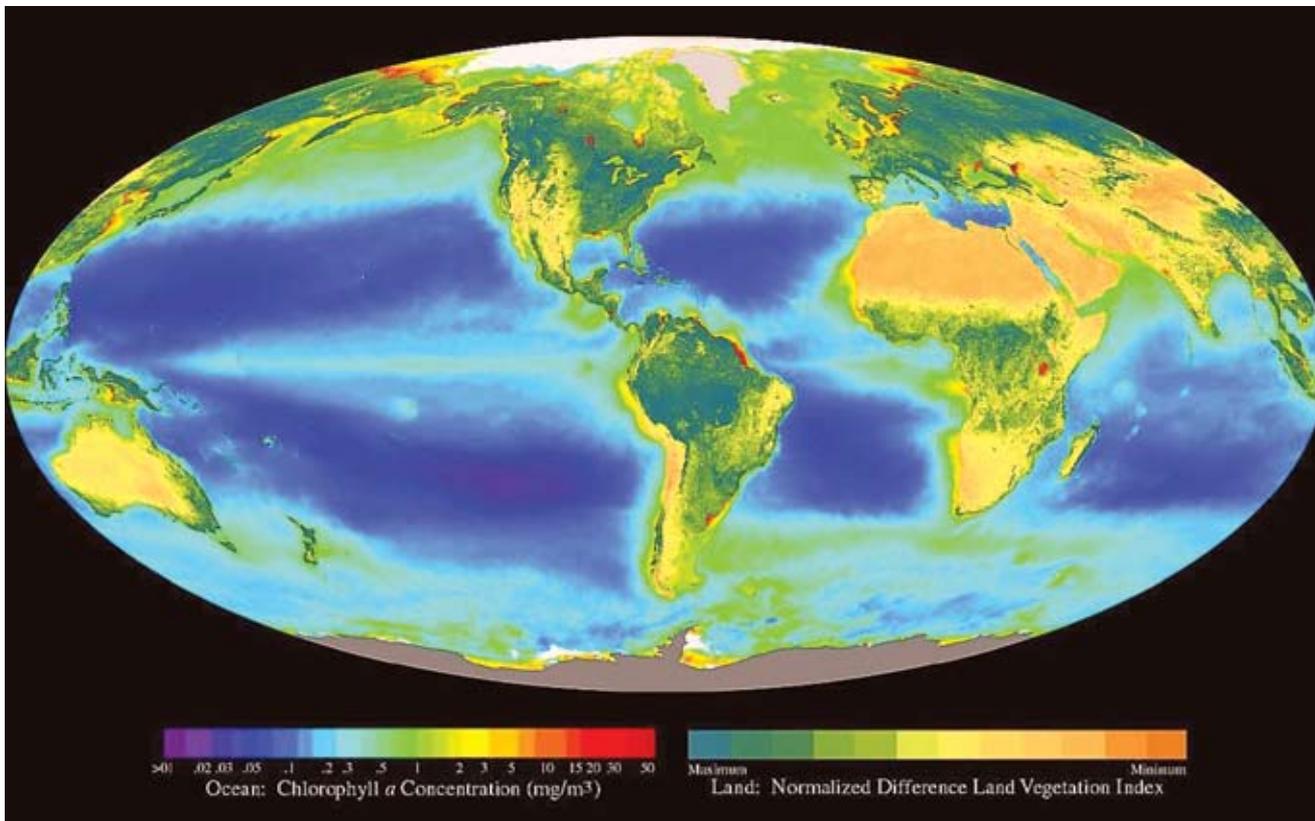
The fractionation hypothesized by Vernadsky, even before much of it was experimentally demonstrated, does exist, and we will look at a few examples, which do not nearly encompass all the work which has been done in that vein. The other side of this question to begin to poke at, is how, or why, this occurs.

Isotopes, as noted above, are typically distinguished by mass, but processes inside living organisms seem to indicate to us that we are only perceiving one shadow of what the actual isotope is, in looking at mass per se. We already know that the organism can perceive qualities such as symmetry. In 1935, Vernadsky said that we should not “overlook the other physiological side of the problem, when it is possible to advance it, that is, the question of the mechanism of the action of the organism upon the isotopic mixtures of elements,” being careful however not to put forward hypotheses about how this would occur.

By no later than 1940, work on potassium fractionation in

6. Vernadsky, *Op. cit.* (Note 2). Also see, Vernadsky, “On the States of Physical Space,” *21st Century*, Winter 2007-2008.

7. Vladimir Vernadsky, “On Some Fundamental Problems of Biogeochemistry,” *21st Century*, Winter 2005-2006.



SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE

A composite image of the global biosphere, using data collected from September 1997-August 1998, showing the magnitude and distribution of global primary production of chlorophyll, both oceanic (in milligrams per cubic meter of chlorophyll) and terrestrial (normalized difference in the land vegetation index).

rats by A.K. Brewer,⁸ known to Vernadsky, already explained fractionation, based on a kinetic mechanism, which is a model that would not have been completely new, since it implies nothing fundamentally different than considerations of how much energy is required to break a bond. Even early writings of Vernadsky, as in 1926, currently being translated,⁹ show him hypothesizing that, even were the isotopic compositions of living and non-living matter the same, reasons of symmetry could account for some difference. This is also referenced briefly in Vernadsky's book *The Biosphere*:¹⁰

"It is very likely that isotopes and the symmetry of atoms play roles in the living organism which have not yet been elucidated," he wrote.

Although this thought is left unfinished, the point is, that Vernadsky was completely confident that there would be a distinction. So, in accord with his general outlook, let us open our minds to some of these questions, and some new and provoking experimental work which shows that the considerations in-

involved are by no means so simple as they are commonly discussed as being.

'Mass-Independent' Isotope Effects

The term "mass-independent isotope effect" has a very specific technical meaning, which we will look into here, to some extent. It is said that a true study of mass-independent fractionation, or a shifting of isotopic ratios from a standard ratio that is not based on mass, can only be measured when looking at elements which have more than two stable isotopes; that when dealing with the fractionation of only two isotopes, or the deviation from some standard isotopic ratio, it can simply be stated that more of the heavier or the lighter isotope is being chosen; this is called mass-dependent fractionation.

Let's look at a couple of examples of what we mean by living processes using isotopes in a "different way," without having to show some variation among three isotopes which vary differently than with mass. It should become clear that the quality of the isotope being perceived by the organism is not simply its weight. Some experts in this field would agree that the organism is not using a scale to judge the isotopes upon entrance, but that bond strengths, for example, are affected by mass. We will not discuss this particular hypothesis much, since more provocative questions loom, even when dealing with so-called "mass-dependent" isotope effects.

For example, specific tissues require unique isotopic compo-

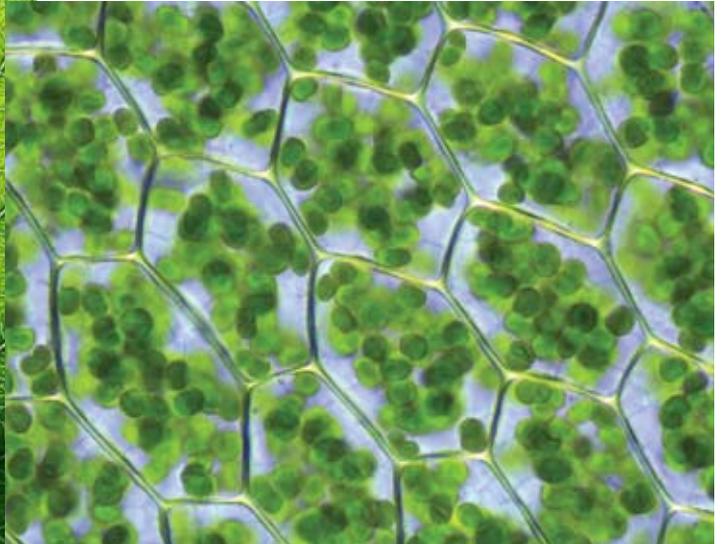
8. A. Lasnitski, A.K. Brewer, "A Study in the Isotopic Constitution of Potassium in Various Rat Tissues," *Biochemical Journal*, January 1941; Vol. 35(1-2): pp. 144-51.

9. Vladimir Vernadsky, in "Work on the Biogeochemistry and Geochemistry of the Soils," Russian Academy of Sciences, 1992 (in Russian).

10. Vladimir Vernadsky, *The Biosphere* (New York: Springer, 1997).



Photosynthesis in plants varies in the uptake of carbon isotopes, with different parts of the plants having more or less carbon-12 or carbon-13. Seeds, for example, tend to be more enriched in carbon-13 than other parts of the plant.



Kristian Peters/creative commons

Plant cells of the moss *Plagiomnium affine*, showing visible chloroplasts. Why do some plants take up heavier or lighter isotopes?

sitions themselves. If it were simply a question of chemical bond yields acted on by enzymes which proceed more quickly with the substitution of a lighter for a heavier isotope, for example, then why would heavier isotopes be used at all? And on the flip side, heavier isotopes strengthen bonds based on their masses. But the point here is to question how the particular ratios are determined for the organism as a whole, without assuming that it occurs as a huge summing-up of individual kinetic and equilibrium effects, if only because isotopes have other, more interesting, ways of potentially interacting with living matter.

In photosynthesis, plants get rid of the heavier of the two main isotopes during respiration. What determines this is not simply which of them, by mass, passes more easily through the same membrane or pore. The prevalence of carbon-12 could possibly be explained this way, in what the plant takes up (more of the lighter isotope—called equilibrium fractionation), but the fact that the heavier isotope is preferentially removed during respiration, showing a reversal of which isotope “passes through,” indicates that this is not so simple a matter.

As researchers on the subject noted in 2004,

Recent experiments on intact bean leaves have shown a significant enrichment in ^{13}C [carbon-13] by about 6% in the CO_2 respired in the dark compared to leaf sucrose, indicating a substantial fractionation associated with respiration.¹¹

Why is it that an overall enrichment in carbon-12 is required in plants with respect to their environment? The matter is not even this simple; looking at the relatively more specialized levels, further differences in enrichment are revealed. Different parts of plants show different concentrations of carbon-13 relative to carbon-12. Lipids, and leaves, in general, appear to be depleted even more in the heavier carbon isotope, while seeds are more enriched in it.



Oak Ridge National Laboratory

Uranium-reducing bacteria may be the cause of the different isotopic composition of some deposits of uranium ore. Here a species of metal-eating bacteria from the genus *Shewanella*, shown here growing on a mineral of iron called hematite.

11. E. Brugnoli and G.D. Farquhar, “Photosynthetic Fractionation of Carbon Isotopes,” in *Photosynthesis: Physiology and Metabolism* (Aarhus, Denmark: Kluwer Academic Publishers, 2004)



Viking Orbiter Image Archive/NASA

The atmosphere of Mars, taken from low orbit by the Viking satellite. Because the Mars atmosphere (unlike that of Earth) is relatively transparent, down to the planet's surface, ultraviolet radiation has produced a different fractionation of some isotopes from that on Earth. We need to find out how this will affect the setting up of an artificial environment for man on Mars.



NASA

An artist's rendering of a polar mission on Mars, where crew members are assembling equipment.

It is even more generally the case that a given "isotopic diet" does not describe fractionation between different tissues and parts of animal bodies. Depletion in blood of the heavier iron isotope with respect to diet; calcium depletion in heavy isotopes in bones versus other tissues; potassium depletion in lighter isotopes in the bones of rats with respect to other tissues; enrichment of the heavier isotope of nitrogen with progression up the food chain and of the lighter isotope of iron—all these are examples of this phenomenon, and a good amount has been written on such particular studies. Mercury in different species of peat moss, from Argentina and Spain, shows, in one case, enrichment, and in the other, depletion, of two odd-numbered isotopes of mercury.¹² (This is technically considered a mass-independent isotope effect.)

Depletion of uranium isotopes in one kind of uranium ore deposit has shown significant depletion of one of the uranium isotopes, and the possible role of uranium-reducing bacteria is not to be ignored.¹³

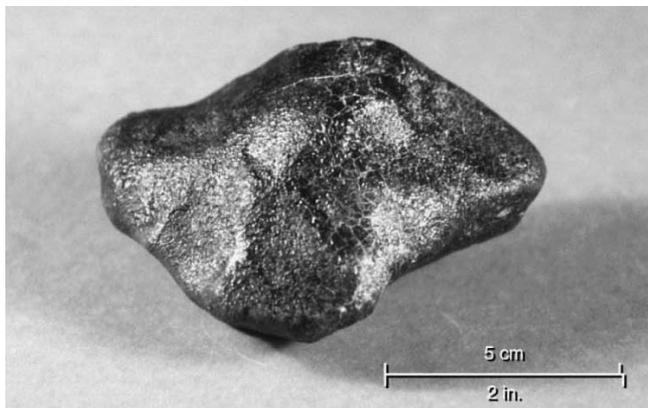
Here's another case of isotopes interacting in an interesting way with life: Experiments have been done on bacteria, in shifting them from water which is "normal" $H_2^{16}O$ to water, in which the hydrogen and the oxygen-16 are switched for deuterium and oxygen-18. Some of these *E. coli* bacteria showed a complete halting of growth for as much as 30 hours, when switched from normal, to isotopically heavy water; others showed significant morphological changes.¹⁴

Was it the weight of the water that caused this effect? As posed at the beginning of this section, some scientists today would explain these effects based on a secondary property of weight, the way in which the weight of the isotope affects certain bond strengths, reducing all but some actually "mass-independent" isotope effects to a simple kinematic model (this is called the kinetic isotope effect). But the question we are intrigued by, is how the overall desired ratio is deter-

12. Sanghamitra Ghosh et al., "Mass-independent fractionation of mercury isotopes in the environment," *Geochemistry, Geophysics, Geosystems*, Vol. 9, No. 3, March 2008.

13. "Uranium isotopes are not invariant, researchers show," <http://www.news.illinois.edu/news/07/1023/uranium.html>.

14. E. Borek and D. Rittenburg, "Anomalous growth of microorganisms produced by changes in isotopes in their environment," *Proceedings of the National Academy of Sciences of the USA*, Vol. 46, No. 6 (June 15, 1960), pp. 777-82.



A piece of the asteroid Vesta. So far, investigations of the isotopic composition of Mars, Earth, the Moon, and the asteroids show that they seem to be similarly enriched in the heavier oxygen isotopes, compared with data found for the solar wind.

mined, and that without simply assuming that it occurs as a summing-up of millions of individual bonds, which are more or less able to be broken by enzymes, for example.

When not in a pure heavy-water environment, water molecules bound to plant cells show a relative depletion of deuterium with respect to a given source of water, seemingly using the deuterium in a precise fashion, if it's not preferentially being released (the model of equilibrium fractionation would not explain that occurrence). Where is the rest of the deuterium going? Why is it more useful somewhere else in the plant?¹⁵

Returning briefly to the subject of the work of Pasteur, and to the subject of whether the isotopes are simply "more or less" of the same element, consider the fact that the lighter or heavier isotopes may serve totally different functions. Amino acids are generally considered to be entirely left-handed molecules, and sugars, right-handed. However, significant cases of right-handed amino acids, though relatively much less abundant, as is the case with heavy isotopes, do exist, and they play a unique role.

One example is an anomalous right-handed version of aspartic acid found in the brains of rats, chickens, and humans, which is present in large amounts during developmental stages, and then rapidly decreases to only trace amounts during adult life. Perhaps the analogy is not exact, but it raises the right question: whether the more trace isotopes are playing a completely unique role, outside of contributing more or less mass to a chemical bond.¹⁶

We can already see that paradoxes arise in explaining the transmission of only two different isotopes across a membrane (that a simple preference for heavier or lighter is not always shown). There was also the role of a given "water environment" in inducing morphological changes in an organism through a switching of isotopes. What is the precise use of a heavy isotope, such as deuterium, in plant water?

15. D. Yakir, M. Deniro, et al., "Isotopic Inhomogeneity of leaf water," *Geochim et Cosmochim Acta*, Vol. 53, pp. 2769-73, 1989.

16. Uwe Meierhenric, "Minority Report: Life's Chiral Molecules of Opposite Handedness," *Amino Acids and the Asymmetry of Life* (Berlin: Springer, 2008).

These examples, although only dealing with two isotopes, would tend to lead us to believe that the matter is not so simple as heavier or lighter being "preferred" or "better for you." The heavier isotopes are generally much less abundant than the lighter ones, so any enrichment in heavy isotopes occurs on a very small scale—another example of a weak force at play, perhaps similar to the crucial role played by low-intensity radiation. It's likely the case that some instances of "mass-dependent fractionation" are simply processes which we do not yet understand, but will tend to explain based on a preference for lighter or heavier through a sieve-like mechanism. Such an explanation coheres with the simplest definition of what an isotope is, though, as an explanation, it leaves much unexplained.

Before moving on to another aspect of this problem, consider already what some of these considerations mean for colonizing a planet like Mars. In 2004, the NASA Genesis mission was deployed to investigate the isotopic composition of the Sun as compared to other planetary bodies. Interestingly, Mars, Earth, the Moon, and the asteroids seem to be similarly enriched in the heavier oxygen isotopes, as compared with what data were found for the solar wind, and the Allende meteorite, which is thought to contain some of the oldest material in the Solar System.

Nitrogen, another element crucial for life, is enriched 4.5 times more in the heavier isotope on Jupiter's moon Titan than on Earth. How would life be able to adapt to such conditions, in an environment depleted of heavy oxygen isotopes, or significantly enriched in heavier nitrogen isotopes?

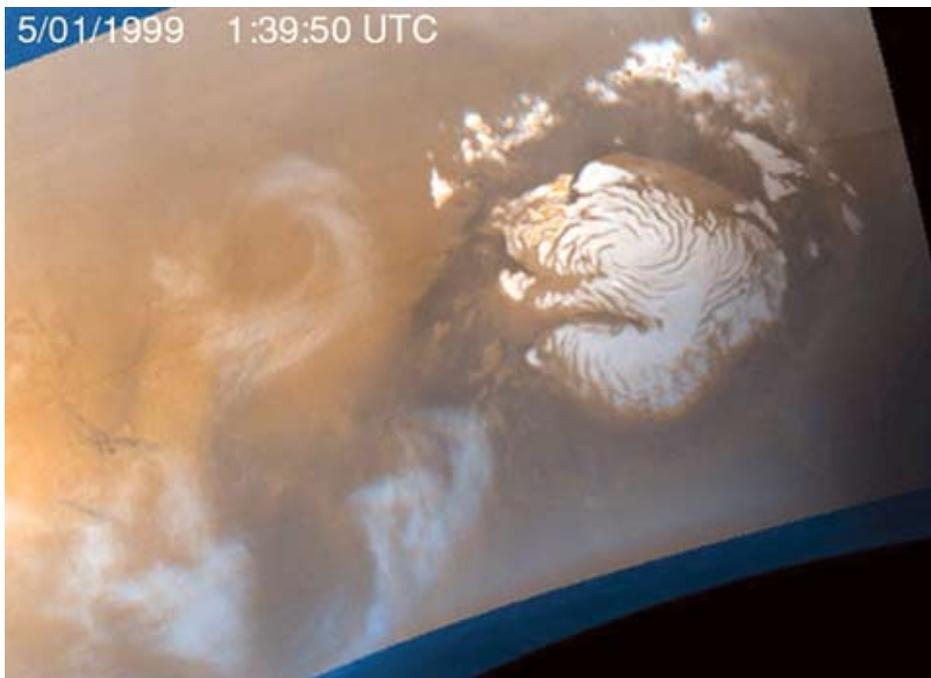
In June 2008, the Phoenix Lander on Mars found the soil to have substantial amounts of magnesium, sodium, potassium, and chlorine, all elements important for plant growth on Earth. But what is the isotopic composition of these elements on the Martian surface? How would plants grown on Mars be affected if the isotopic composition of the soil were significantly different from that on Earth, and how would we compensate for that difference, if needed? An initial glance at the role of isotopes in life has shown us that such factors are not to be overlooked.

Fractionation of Planetary Atmospheres

Other interesting examples of mass-independent fractionation do occur in cases where there is a clear variation between two isotopes, from proportions of them increasing or decreasing with mass. A much studied case, is that of ozone, where



The fractionation of isotopes of sulfur (left) in rocks and magnesium (right) in photosynthesis is still under investigation, with speculation as to the causal mechanism.



NASA/JPL/MSSS

A midsummer storm in the northern hemisphere of Mars. The seasonal enhanced heating leads to the release of water vapor into the atmosphere, and the temperature differences create winds that mix the atmosphere and create waves of clouds that swirl around the polar cap.

among oxygen-16, oxygen-17, and oxygen-18, there is a spike in the amount of oxygen-17 present in ozone molecules, relative to what the expected enrichments would be if they depended on a scaling with mass. There is an almost equal enrichment of oxygen-17 and oxygen-18, and a relative abundance of the totally asymmetric ozone molecule $^{16}\text{O}^{17}\text{O}^{18}\text{O}$. Reasons related to the elusive quantity of “electron spin,” and a resulting asymmetry of the molecules, are hypothesized by most current scientists as being causal factors.

Also, the role of photolysis, or ultraviolet radiation, in producing a kind of mass-independent fractionation of sulfur in rocks from the Archean Earth atmosphere has been posited, through a type of resonance which the radiation has with certain molecules, which can be different based on isotopic makeup. Each of these cases deals with three or more stable isotopes, so a depletion or enrichment of only one, or of two evens or odds, is what is called a mass-independent fractionation.¹⁷

In general, there does not seem to be consensus on the matter of how atmospheric fractionation occurs, as is stated in one recent article:

Currently, in spite of fifteen years of intensive experimental and theoretical investigation after the first observation of a chemically produced mass-independent process, the mechanism that is responsible remains unidentified.¹⁸

17. A.A. Pavlov, and J.F. Kasting, “Mass Independent Fractionation of Sulfur Isotopes in Archaean Sediments: Strong Evidence for an Anoxic Archaean Atmosphere,” *Astrobiology*, Vol. 2, No. 1, 2002.

18. Mark H. Thiemens, “Mass-Independent Isotope Effects in Planetary Atmospheres and the Early Solar System,” *Science*, Vol. 283, 1999.

atoms in the atmosphere through living matter and back into the atmosphere once every couple of thousand years.¹⁹ The unique isotopic effects produced in the atmosphere are ultimately intimately connected with the creation of the atmosphere by life.

But aside from that question in particular, this line of thought has already brought us to an important consideration regarding our future colonizing of other planets. Think of the question regarding the nature of the Martian atmosphere. Researchers looking at similarities between the Archean Earth atmosphere and the Martian atmosphere have pointed out that the photolysis which created fractionation of sulfur dioxide on Earth years ago in a low oxygen atmosphere, a result of UV radiation, is active on Mars all the way down to the surface, and produced a similar fractionation of sulfur isotopes there, that is still active:

There are major differences between the Martian and terrestrial atmospheres. The most obvious difference is that water photolysis is important all the way to ground level on Mars; this is due to the relative transparency of the Martian atmosphere.²⁰

How will this kind of fractionation affect our efforts to create an artificial environment on Mars, with compounds such as water vapor (preferentially over heavy-water vapor) being split all the way down to the surface? How will this type of fractionation

19. Eugene Rabinowitch and Govindjee, “Photosynthesis,” <http://www.life.illinois.edu/govindjee/photosynBook.html>

20. C. Miller and Y. Yung, “Photo-induced isotopic fractionation,” *Journal of Geophysical Research*, Vol. 105, No. D23, 2000

affect the atmosphere which we create in its initial phase, as well as chemical compounds more generally?

'Spin': A Purely 'Physical' Quantity?

The special role played by magnesium-25 in photosynthesis is a much-touted case. This isotope's unique "spin," as mentioned, a quantity made hard to understand because of the obscure nature of quantum mechanical language, is hypothesized by many current scientists as being causal. The presence of this isotope has been shown to speed up the rates of formation of ATP (adenosine triphosphate) in photosynthesis when it is present in a specific enzyme.²¹ Rather than getting into the technicalities of how this is supposed to work, let us look instead at some recent experimental work, not directly related to magnesium isotopes of photosynthesis, but work which is very interesting, keeping in mind Vernadsky's initial provocation that chemical processes within a living organism will be different from chemical and physical phenomena which we observe outside of that context.

Electron spin, and its ability to be affected by different isotopes of the same element, is usually discussed as possessing a type of resonance with magnetic fields. The concept of "spin" is also carried over from atomic electron to nucleus. For example, MRI/NMR (magnetic resonance imaging/nuclear magnetic resonance) imaging technology exploits the weak magnetic characteristics of some isotopes. But does spin itself simply refer to the state of an atom which is determined by, and determines, purely "physical" reactions? Recent experimentation has demonstrated the interesting phenomenon of "spin-polarized electrons" (some kind of coordination of spins) being "asymmetrically scattered" after interacting with films of chiral (left/right-handed) molecules.

As one researcher noted:

A successful observation of electron optical dichroism (not rotation per se, as occurs with Pasteur's experiments with polarized light, but "spin-dependent attenuation" [a kind of loss of intensity or scattering—MKR] was eventually achieved by enhancing electron scattering through the addition of a ytterbium atom to camphor-based organic molecules to form (x compound) and analogous compounds. . . . I express my admiration for this elegant experiment. Other experiments have since been done to observe the asymmetric scattering of polarized electrons by organic films of thin chiral molecules. As of this writing, I am not aware of experiments that have observed the electron analogue of optical rotation. The preferential interaction of spin-polarized electrons with chiral molecules has attracted attention. . . .²²

While the details of how these experiments are carried out are important,²³ and have not been discussed in depth here, for our

21. J.R. Black, "An experimental study of magnesium isotope fractionation in chlorophyll-a photosynthesis," 2006, <http://www.escholarship.org/uc/item/8x5346hj>

22. "Chiral Asymmetry: The Quantum Physics of Handedness," in Mark P. Silverman, *Quantum Superposition: Counterintuitive Consequences Coherence, Entanglement, and Interference* (Berlin: Springer, 2008).

23. <http://www.uni-muenster.de/Physik.PI/Hanne/chiral.html>

purposes, the significance of this, admittedly hard-to-conceive-of experiment, is that of the interaction of the quantity of spin with that of molecular chirality (handedness), which Vernadsky and Pasteur pointed at as being a unique characteristic of biological chemistry, its preference for and creation of these molecules. Many mass-independent isotope effects are explained based on spin numbers and "magnetic moments" of isotopes, including inside of the organism. But here is already an indication of a potentially unique "resonance" of electron spin, and chiral molecules, which we know to be characteristic of life.

Isotopes and Molecular Chirality

So, after all this, the question remains: what is being "perceived"? Mass? Spin? The spectra of the isotopes? How about the symmetry of the molecules? Which of these characteristics is the analogue to Pasteur's isomers (compounds with the same molecules, but different structural formulae) for isotopes? Perhaps we can not answer this question until more experimentation is done, but it is clear that isotopes, and living things, interact in a way which still remains hidden to us, but which does lead the mind in the direction of recognizing the interaction as very unique. However, one of those particular quantities may have caught your eye: the symmetry of the molecule itself.

We know this was Pasteur's focus, but what could this have to do with isotopes? The anomalous abundance of the completely asymmetric ¹⁶O¹⁷O¹⁸O ozone molecule was referenced briefly, but it is sort of a step removed from life (although we will not assert that the atmosphere as a whole is non-living, as it is largely produced by life). In fact, more direct work has been done recently with respect to this asymmetry of molecules as a result of an isotopic substitution, creating a different notion of chirality.

In a work whose translation is pending, Vernadsky indicates that there should be something beyond molecular symmetry as a unique indicator of life's physical space-time, at the atomic level. He seems to imply that, even were there similar isotopic compositions between living and non-living matter, we should still assume there would be a difference, related to symmetry. What could this mean? This author would be inclined to think Vernadsky is discussing the possible significance of asymmetric molecules which contain both isotopes, or "isotopomers."

And in fact, some recent experiments have been done by substituting, for example, a carbon-12 for carbon-13 isotope in a compound which, when it typically reacts with another specific compound, produces a totally racemic mixture of molecules, or, in other words, handed molecules where there is generally a 50/50 abundance of each isomer (the normal symmetrical molecules discovered by Pasteur).²⁴ This experiment was done by reacting pyrimidine-5-carbaldehyde, and diisopropylzinc, which created an enantiomorphic excess in the resulting zinc alkoxide; similar results were also shown for other reactions.

So, it has been shown that this ratio can be shifted through the "doping" of the catalytic compound. Here is another possibly unique role of isotopes in the living organism. It is not clear if any study has been done to determine the abundance of these new isotopically "chiral molecules" in life, but it is very intriguing to consider based on the uniqueness of handed mol-

24. Tsuneomi Kawasaki, et al., "Asymmetric Autocatalysis Triggered by Carbon Isotope Chirality," *Science*, Vol. 324, p. 492, April 2009.

ecules in life, as we have continued to emphasize, and a potentially unique and even catalytic role in forming these compounds by isotopically asymmetric molecules themselves, which life could potentially create. Does the overall fractionation in a living thing require a certain number of these new chiral structures?

Radioactive Potassium on Mars?

In an adult male, there are about 140 grams of potassium, of which a small, but powerful portion is the radioactive isotope of potassium, which produces, in total, about 80 decays per minute.²⁵ This isotope is small in abundance, but potentially has played a very important role in evolution, with seven times more of it being present 3.5 billion years ago, its action largely occurring within cells.²⁶ What is its role, in general, in human, animal, and plant physiology? Vernadsky knew of the work of the Dutch researcher Zwaardemaker, who did experiments where he pumped salt solutions through eel and frog hearts, claiming to have “revived them,” due to the presence of radioactive potassium, and salts of other radioactive isotopes. While we cannot speak to the validity of this claim, or the precise role of radioactive potassium in the body, there is every reason to classify this, as well as the general phenomenon of isotope fractionation in the body, as a powerful, but weak force.²⁷

But, again, we are confronted with another consideration which has implications for our colonization of Mars. Recent studies have been done indicating that there is possibly a direct impact upon nuclear decay rates based on the changing Earth-Sun distance throughout the year, in experiments done on radioactive isotopes of silicon, radium, and chlorine. An annual modulation in decay rates taken over 15 years, in some cases showed this correlation,²⁸ and similar experimental results were found in putting other decaying samples into rotating centrifuges—potentially related, since this could mimic gravitational effects.

In asking ourselves how we will support healthy humans on Mars, these considerations are crucial; even if only hypothetical, they indicate the kinds of problems we will need to consider. What if the decay of potassium-40 in the body is less on Mars, let alone if there is less of it overall? What is its role in the human body, and how would a change in its decay rate affect that? Would Martian soil need to be enriched in potassium-40 to compensate? This is the kind of thinking which shows how intrinsically linked the science of physical economy and physical chemistry are, in fact.²⁹

25. “Exposure of the population in the United States and Canada from natural background radiation,” National Council on Radiation Protection and Measurement; NCRP 96 (Bethesda: 1987).

26. F. Moore and K. Sastry, “Intracellular Potassium: 40K as a primordial gene irradiator,” *PNAS*, Vol. 79, No. 11, June 1982, pp. 3556-59.

27. James Muckerheide, “Time To Tell the Truth about the Health Benefits of Low-Dose Radiation,” *21st Century*, Summer 2001.

28. Jere H. Jenkins, Ephraim Fischbach, et al., “Evidence for Correlations Between Nuclear Decay Rates and Earth-Sun Distance,” August 2008; arxiv.org/pdf/0808.3283v1; and He Yujian et al., “Changes of decay rates induced by mechanic motion,” *Science in China*, Series B: Chemistry (Berlin: Springer, 2008).

29. At this point, it is appropriate to reconsider the quotation from Lyndon LaRouche, “The Secret Economy” cited at the outset of this report.

Calls for Further Experimentation!

We see paradoxes in isotope fractionation which indicate to us that there are clearly characteristics of the real thing we refer to as “the isotope” other than mass. What facet of the isotope does the living organism perceive, or require? Is it some kind of required symmetry, as seems to be the case with Pasteur’s isomers? While we may not have an answer, at least we can say that some of these questions have led us in the right direction, elevating our conception of what the interaction could be.

So-called “mass-dependent” isotope fractionation would seem to indicate, that inside of the living organism, processes are occurring according to simple kinematic or equilibrium laws, such as diffusion across a permeable membrane. However, Pasteur has led us to believe that there is something other than a simple physical or chemical space inside of a living thing, which is why mass-independent isotope fractionation, particularly if it is symmetry-driven, is cause for excitement, and definitely calls for new modes of experimentation. It seems to be a field of experimentation avoided by biologists, who perhaps feel the shadow of Alexander Oparin towering over them, urging them to believe, despite Pasteur and Vernadsky, that life is not a unique and higher phase space, than the non-living domain. (The only explicit references in a scholarly article to “mass-independent-fractionation” in life found by this author, are the examples of magnesium-25, and the varying compositions of mercury isotopes in peat.) It were also a very good idea to do as Vernadsky wished: to examine isotope fractionation for all elements in living organisms, not just the most abundant ones.³⁰

Although it seems that there are more questions than answers available to us, we have every reason to believe that Vernadsky’s insistence on the distinction of the three universal phase-spaces will be vindicated in the domain of isotope fractionation and usage within the living thing. More focussed experimentation, with an eye towards Vernadsky’s hypothesis, is long overdue!

This initial investigation of isotopes and their relationship to life is an important aspect of considerations we must take into account in planning to colonize space, if we wish to do it successfully. In such an endeavor, ideological approaches to questions about life as such will be of no help at all, as we attempt to try to keep humans alive on the Moon and Mars, for starters. The living organism does not exist independently of a whole array of relatively weak forces, including cosmic and electromagnetic radiation,³¹ universal gravitation, and the unique isotopic composition of its environment, from which relatively small enrichments of already sparse isotopes are produced. Attention to such relatively weak forces is what will put us in the best possible position for supporting the seemingly weakest, yet truly most powerful force, human creativity, on Mars.

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30. “We are faced with a general problem. Is the change of a chemical element with a different atomic weight by the life process restricted to some new chemical elements, such as hydrogen and potassium, or is this a phenomenon common to all organisms and all the chemical elements?” Vernadsky, *Op. cit.* (Notes 2 and 7).

31. Oyang Teng, “Onward to Mars: The Triumph of the Weak Forces,” *21st Century*, Spring 2010.