Book Review

Deep biosphere theory poses revolutionary challenge to prevailing conceptions

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The Deep Hot Biosphere
by Thomas Gold
New York: Springer-Verlag, 1998
235 pages, hardbound, $27

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Scientists aware of the fundamental problems of biology should read Thomas Gold's book. It is rich in content and the author identifies, competently and precisely, the stakes of the issues raised, laying out the consequences of his approach to different fields of knowledge. As this thorough study makes no assertions, it is a powerful antidote to the dogmas that thwart revitalization of our general biological conceptions.

Gold opens the debate with what appears to be an innocuous question: "Does the Earth really represent the best conditions for life?" We will present below Gold's arguments, adding only a comment on their implications, and then, we will attempt to give a short, more personal, point of view concerning their scientific and technological consequences.

As the Earth was formed by the accretion of cold, solid fragments condensed from a nebula surrounding the Sun, a great many of the materials acquired in this way, including many hydrocarbons, avoided being subjected to excessive heating. The liquids and gases temporarily trapped in porous sedimentary rock were freed as the internal heat of the globe increased, and, since they were less dense than rock, were pushed up to the surface. Gold points out that hydrocarbons, spanning the chemical spectrum from methane to the heaviest petroleums, can be found today inside the Earth in far greater quantities and at greater depth than generally believed. Thus, we have the basis for the Deep-Earth Gas Theory, an abiogenic explanation for the formation of hydrocarbons.

Many observations and experiences indicate that a significant array of life existed—and still does—beneath the surface of the biosphere that man inhabits. This below-surface domain and its inhabitants make up Gold's "deep hot biosphere," which extends downward 10 kilometers or more. Given the natural temperature gradient, the temperature in this area may be over 100°C. Gold opposes, or compares, this living domain to the biosphere that we know, which he calls "the narrow window of life at the surface."

The bio-energy question

In one telling remark, Gold says that "the photon has no patience," that is, if it is not used immediately (thanks to adequate receptors), it is lost forever. Solar energy used on the surface is therefore costly.

Gold insists on the basic notion that "only a metered flow of energy" could have allowed life to develop over a long period of time: tens or hundreds of millions of years during which a vast number of molecular "experiences" could take place. The notion of a small, warm breeding ground (the classical "primordial soup"), containing nutrients which surface processes have painstakingly elaborated, is not the kind of environment that would have allowed the transition from non-life to life, he writes. It would be more logical to think that the *original* source of energy for life on Earth was not derived from photosynthesis, but, in an earlier stage, from the oxidation of hydrocarbons that were already present *in* the Earth, *in the same way* that they are present on many other planetary bodies, as well as within the original materials that formed the solar system. That is where the regular flow of energy necessary for life would be found.

Therefore, he hypothesizes that life began at great depths, under high pressure and at high temperatures, and the carbon reservoir and basic chemical foundation was methane (CH_4). These particular physical conditions allowed for the non-dissociation of hydrocarbons (C_nH_n) and of other more organized molecules, into carbon dioxide and water (CO_2 and H_2O), and for easier spontaneous synthesis of complex molecules. Then, following his hypothesis, the chemotroph unicellular stage (Gold's *Archea*) was reached. Finally, the single cells from the deep hot biosphere probably invaded the zone along the

surface biosphere, long before the emergence of the photosynthetic processes that created the conditions for the synthesis of complex molecules to take place at the surface. Before photosynthesis transformed the Earth's surface into a zone infiltrated by free oxygen molecules, it is possible that the chemical differences between the two worlds were very slight.

Gold also shows, through well-grounded estimations, that the total volume of rock accessible to certain unicellulars (comparable to the chemotrophic archeobacteria) is enormous; the microbe content of the Earth's upper crust may exceed, in mass and volume, all life on the surface.

When Thomas Gold began developing his concept of the deep hot biosphere in the 1980s (published in 1992), one of the grounds for criticism was that the sample microbes brought up from oil and gas wells were not native, but the result of contamination from the surface (by fluids used as lubricants during drilling). Then, in 1995, Guy Ourisson of France published an article showing that microbes picked up by drilling rigs at a depth of 1.6 kilometers were really members of an indigenous deep thermophilic community. The following year, indigenous unicellulars were discovered from drilling in Alaska at a depth of 4.2 kilometers where the temperature is 100°C. In 1997, the indigenous hypothesis was confirmed by discovery of microbe fossils in *granite rock,* at 200 meters below the surface. Contamination by drills is ruled out in this case.

Keeping in mind Gold's theories, it is useful to mention some recent discoveries: those of various fauna (single-celled and invertebrate) near sulfur outpourings coming from deep-ocean pits, and those of unexpected and, until then, unknown ecosystems in underground networks, in Romania (1986), then Mexico (1997).

Conflicting theories on the origin of oil

According to Gold's theory, natural gas and other hydrocarbons originated at 100-300 kilometers below the Earth's surface.

By contrast, according to the classical biogenetical theory on the origin of petroleum, adopted in the 1870s, the Earth was formed as a very hot body, perhaps as a kind of melted rock. In this case, no hydrocarbon participating in the accretion would have survived: It would have been oxidized into CO_2 and H_2O. But, according to the same theory, biological debris from the Earth's surface, buried in sediment, would have decomposed into natural oils and gases over the course of time. The oil would then have been concentrated into the porous spaces of the sedimentary rocks, in the outermost layers of the crust. The oil would migrate over time and collect itself in preferential trap-strata.

Gold's abiogenic theory implies five hypotheses, which he defends:

1. Hydrocarbons were the common constituents of the primary materials from which Earth was formed.

2. During the 4.5 billion years since the Earth's accretion, the primary hydrocarbons were not completely dissociated into CO_2 and H_2O.

3. Hydrocarbons must be chemically stable in the high-pressure, high-temperature conditions found deep within the Earth.

4. Hydrocarbons must have found—or created—pores deep into which they could settle and then migrate toward the Earth's surface.

5. Deep-Earth sources of hydrocarbons still exist.

Hopanoid molecules

Guy Ourisson and his team researched hydrocarbons belonging to the group called hopanoids. These molecules, derived from the degradation of fossil cell membranes and found in many samples of different petroleums, came from sediments of very diverse ages and places.

According to Ourisson, the stock of hopanoids on our planet should be about 10^{13}-10^{14} tons, i.e., between ten and one hundred times more than the estimated amount of 10^{12} tons of organic carbon located in all living organisms. As for the biomass that generated them, it would be consciously underestimated, insofar as only bacteria and what are called archeobacteria (Gold's methanotroph *Archea*) contain hopanoids with molecules of 35 or 36 carbon atoms. None of them is exclusively tied to the macroflora or fauna. Consequently, according to Gold, surface life could not explain the presence of biological molecules in sub-surface hydrocarbons.

Experimental drilling in Sweden

Beginning in the 1980s, Gold was convinced that the abiogenic theory of petroleum formation was correct, and sought to demonstrate it by proving that hydrocarbons existed in great depths and in a type of rock that contradicted the biogenic theory. Once he aroused the interest of Swedish geological and economic authorities in his project, he started doing depth drilling in non-sedimentary rocks. The main technical problem involved eliminating the risk of contamination from above, during the drilling.

In addition to unexpected amounts of natural hydrocarbons, the drillings brought up, at first, inexplicable amounts of zinc trapped in magnetite crystals (a special iron ore), as well as a lot of iridium. Gold contends that it is unrealistic and dogmatic to try to explain with the biogenic theory the quantities of magnetite, zinc, and iridium accompanying the upwelling of hydrocarbons. To prove or disprove his abiogenic theory, large outlays would be required, on the one hand, for drilling, and on the other, for culturing (under high pressure and temperature) and for study of organisms (archeobacteria) brought up from these great depths. Gold regrets the fact that, in spite of the great scientific, technical, and economic interest of such research, no major scientific magazine published the results of his drillings in Sweden. The "referees" maintained that the results were too incredible to

be published. Although Gold invited geological organizations to send delegations and observers to the drilling sites, they declined.

The origin of life

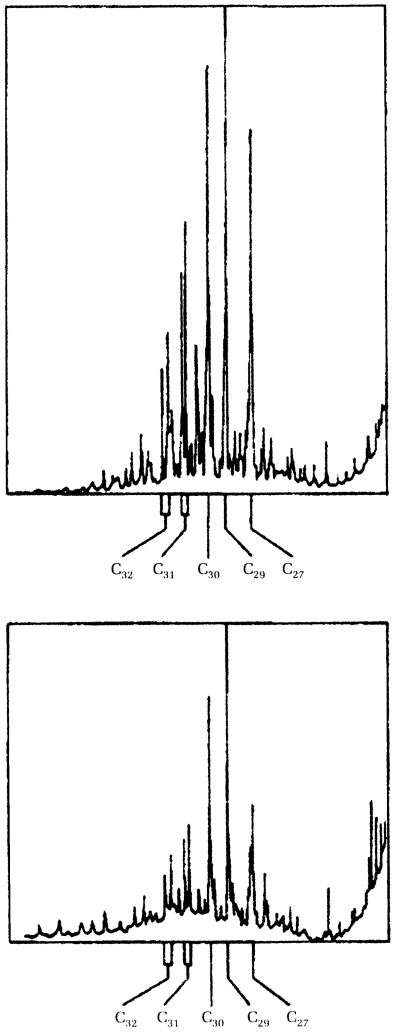
Gold's theories are a direct challenge to prevailing conceptions on the origin and evolution of life. We will summarize his theories: Earth, he contends, sustains two major domains of life: surface life fed by photosynthesis, and deep life fed by chemical energy. He believes that research on deep life can only begin in earnest when the unicellular structures brought up from the depths are perceived as representing a biosphere different from the surface biosphere. If such an awareness does, indeed, sink in, it will spark, in his view, a true explosion of ideas within the whole cultural field concerning the origin of life and extraterrestrial life.

Moreover, Gold writes, detailed chemical analyses show that the two domains of life on Earth (our biosphere and the deep hot biosphere) have a common origin, since they have the same genetic system. He poses afresh, in modern terms, the pan-spermic hypothesis: Is it not the case that the transportation of biological material between heavenly bodies would mean that life would develop, depending on local planetary conditions, first on the surface or at depth, and thence extend to the other, initially uninvolved domain? It seems to him that seeding of the sub-surface would have been the most probable initial place, with life beginning to develop deep down where it is protected, shortly after the planetary accretion. The abundance of carbon molecules in this habitat would have increased the chances of highly organized molecular complexes developing.

Gold proposed his Deep Earth Gas Theory during the period of the energy crisis. He contended that that crisis relied on unfounded geological dogmas and was implicitly motivated by financial considerations. He shows that, insofar as what is qualified as "non-renewable fossil fuel" (beginning with oil), is the product of many mineral deposits, this could be thanks to inadequate investigation and comprehension. He thinks the fundamentals of mineral geology should be reinterpreted.

While attempting to demonstrate the consequences of his theories, Gold mentions something that gold miners from Colorado, California, the Yukon, and South Africa were well aware of, which is linked to the idea of the "black leader." The permanent upwelling of hydrocarbons, from the depths of the Earth's crust toward the surface, occurs in tandem with the upwelling of metals and carbon deposits in their various mineralogical forms.

He explains that geological and mineral research is hampered by a "surface chauvinism," so that those who study the Earth do not recognize the presence of chemical energy under their feet. As a result, astronomers and planetologists have not been able to elaborate a "sub-surface" component to their research on extraterrestrial life.



Similarity in hopanoids (molecules attributed to bacteria) detected in a coal sample and an oil sample, both from France. The upper chromatogram was obtained from Lorraine coal residing in strata dated at about 300 million years. The lower chromatogram comes from a heavy crude oil that is found in strata of the Aquitaine Basin, dated at about 150 million years. A comparison shows that coal and oil had a similar complement of bacteria, depositing the unusual form of the biological debris. The age estimates are for the containing rock; the carbon may have been laid down later.

This similarity is difficult to explain, Gold says, under the biogenic theory, because that theory holds that coal is the altered remains of land plants, while oil is the altered remains of marine biological debris, and it is unlikely that the same microbiological material would be found in both.

Source: Guy Ourisson, Pierre Albrecht, and Michel Rohmer, 1984, "The Microbial Origin of Fossil Fuels," *Scientific American,* Vol. 251, No. 2, pp. 44-51, as reproduced by Gold, p. 93.

If Gold's theories are proven, the rethinking that would have to be done would cover a great deal of our culture, as well as of our sciences, technologies, and humanities. Let us summarize them with a comment.

- We have already seen that proving Gold's theses should

stimulate research in fundamental geology: the process of the Earth's formation, possible participation of cosmic hydrocarbons in planetary accretion, the evolution of these hydrocarbons, the acceleration of deep drilling programs to gain better knowledge of the Earth's crust.

• In mineral geology, research should lead to a better understanding of the development of mineral deposits. This should improve the selection of fields to be prospected for one or another mineral resource. A better understanding of the Earth's crust, the subsequent improvement in techniques for gaining access to deeper regions of the crust, should open the way to discovering mineral deposits that we may not even imagine today.

But if Earth is no longer an exception in the universe, if life is finally conceived of as a necessary *or* very probable *process, then the famous Romantic solitude of the probability biologists will give way to a completely new human adventure, whose setting is no longer limited to Earth, but the cosmos. Philosophy will have to catch up to the school of new biological discoveries.*

• As Gold began to do, we should also rethink how the Earth presently throws off gases and, at the same time, reinterpret atmospheric chemistry and physics. Gold's research would indicate that we should take into account a greater outgassing than present estimates do. If that were done, then we would probably have to revise downward the effects that our industrial waste is estimated to have on atmospheric balance, for example, CO_2.

• All our present biological conceptions should also be reexamined. If there really existed a deep hot biosphere whose biomass were greater than that of the surface biosphere—and if it still does exist—then the "center of gravity" of many of our debates would unexpectedly shift. We cannot characterize here this new enlightening. One of our minor differences with Gold is that we don't think such a sharp distinction should be made between a surface biosphere (the one in which we live) and a sub-surface biosphere. He himself gives a fundamental reason for that: their genesics (concerning their origin) and genetic unity. To separate these two domains of adaptation (over time and in space) from the living process, is already using the same type of thinking as the mechanistic dogmas he criticizes: We first look for the limits and oppositions to life, and think that by conceptually breaking up the continuum of life, we will gain access to the succession of forms and to transformations. Thus, the evolution of the global process is poorly understood and distorted, because the reference discontinuities we *thought* we recognized, are not significant, or are only arbitrary perceptions. We will have failed to seek, in the depth of the continuum, the fundamental law of growth which *orders its unique body into singularities,* both in time and in space.

• Following on the preceding considerations, we are led to ask about the view of the origin of life accepted today. Consistent with his thinking, Gold writes that it might be incorrect to say that there was a definite beginning to life. That is also what we set forth in 1991,[1] stating that life was perhaps a "property" of the universe. Gold thinks it is possible that there was a step-by-step progression toward greater complexity. Life, he writes, might represent nothing more than a process like those described in physics or in chemistry. This new light thrown on life would break open the thorny dogmatic problem of what we call "biological geocentrism." We would become aware that there may not be more of a limit (a frontier) between life on Earth and other forms of cosmic life, than there would be, in our view, between Gold's deep biosphere and our better-known surface biosphere. Research will only really begin, once it has been understood that life is a process on a cosmic scale, which has no more tight compartments than does the *inert "phase"* of the universe: In this conception, life would be a whole of cosmic space-time dimensions, as a process going together with (or participating in) the universe that we now conceive of as being "physical" (this would be the *living "phase"*). In this case, if life exists on a universal (cosmic) scale and develops unitarily (the fundamental law of growth), we would have to rethink, on that scale, all the issues.

As a last remark, we should then not be surprised to find very comparable forms of life (taking into account environmental disparities) on other planetary bodies, including for human stages of evolution: Given the same evolutionary stages and neighboring environments, we would find solutions similar to one another.

Such a shattering of the way we represent the sphere in which life develops and man lives (more precisely, where different human stages live)—a beneficial shattering for both science and technology—would bring about a similar explosion in all branches of knowledge concerned with man and his place in the universe. Man would need some 50 or 100 years to get used to it. But if Earth is no longer an exception in the universe, if life is finally conceived of as a *necessary* or *very probable* process, then the famous Romantic solitude

1. Jean-Michel Dutuit, "Mort et Reviviscence du Géocentrisme," Medispace III, 3 and 4 (July-October 1991), 249-265.

of the probability biologists will give way to a completely new human adventure, whose setting is no longer limited to Earth, but the cosmos. Philosophy will have to catch up to the school of new biological discoveries.

• If it is obvious that Earth sciences and technologies should undergo a certain number of fruitful challenges and developments, taking into account Gold's theses and the end of "biological geocentrism," it takes only one more mental step to understand that planetology and related technologies could also be thoroughly shaken up. Gold introduces this way of thinking and this questioning in connection with Venus and Mars. On the basis of recent pictures of Mars's surface taken by probes, he decreases certain estimates regarding the amount of available water on Mars. He thinks the pattern of some catchment networks on this planet is due more to the movement of ice than of water. And he insists that Martian ice is rather sublimated than liquefied. In any case, what we find to be essential in Gold's book are not these analytical views. The essential point is how he reinterprets the fundamentals of the geology of different planetary bodies.

Let us specify here that we prefer the term "becoming habitable" (meaning a planetary body) to "terraformation." Indeed, the latter is tainted with geocentric dogmatism, distorted by too many presuppositions and by a certain naiveté, if only because it implies that we should make the relevant planetary body "similar to Earth," beginning with the atmosphere. We should beware, that words can be a pitfall for our thoughts and their good intentions! There is no proof that the solutions for other planetary bodies becoming habitable will not be faster, more rational, and more economical if we use radically different means than those "discovered" for life on Earth, and better adapted to the relevant planetary milieu: for example, by acting at the same time on the host planet, and on human physiology and genome.

• Let us add one last, brief remark on biological evolution, even if it was already implicit in the preceding paragraphs. Although Gold remains (in our view) too trapped into the present probabilistic paradigm, he seems to be aware of the artificial, outdated character of Darwinian debates concering the "improbable" aspect of the appearance of life. But he attempts to fight on this ground anyway. He even shows, with striking new argumentation, that the probability of the emergence of life is, in reality, much greater than the Darwinians claim (the metaphor about monkeys rewriting Shakespeare "by chance"). To back up his argument, he uses the explanation of the elaboration of the eukaryote cell afforded by the endosymbiosis theory (of Margulis and others). We extended this theory of "nesting" to all of life, including man, between 1994 and 1997 in *Fusion* magazine and other broader, as-yet-unpublished writings.