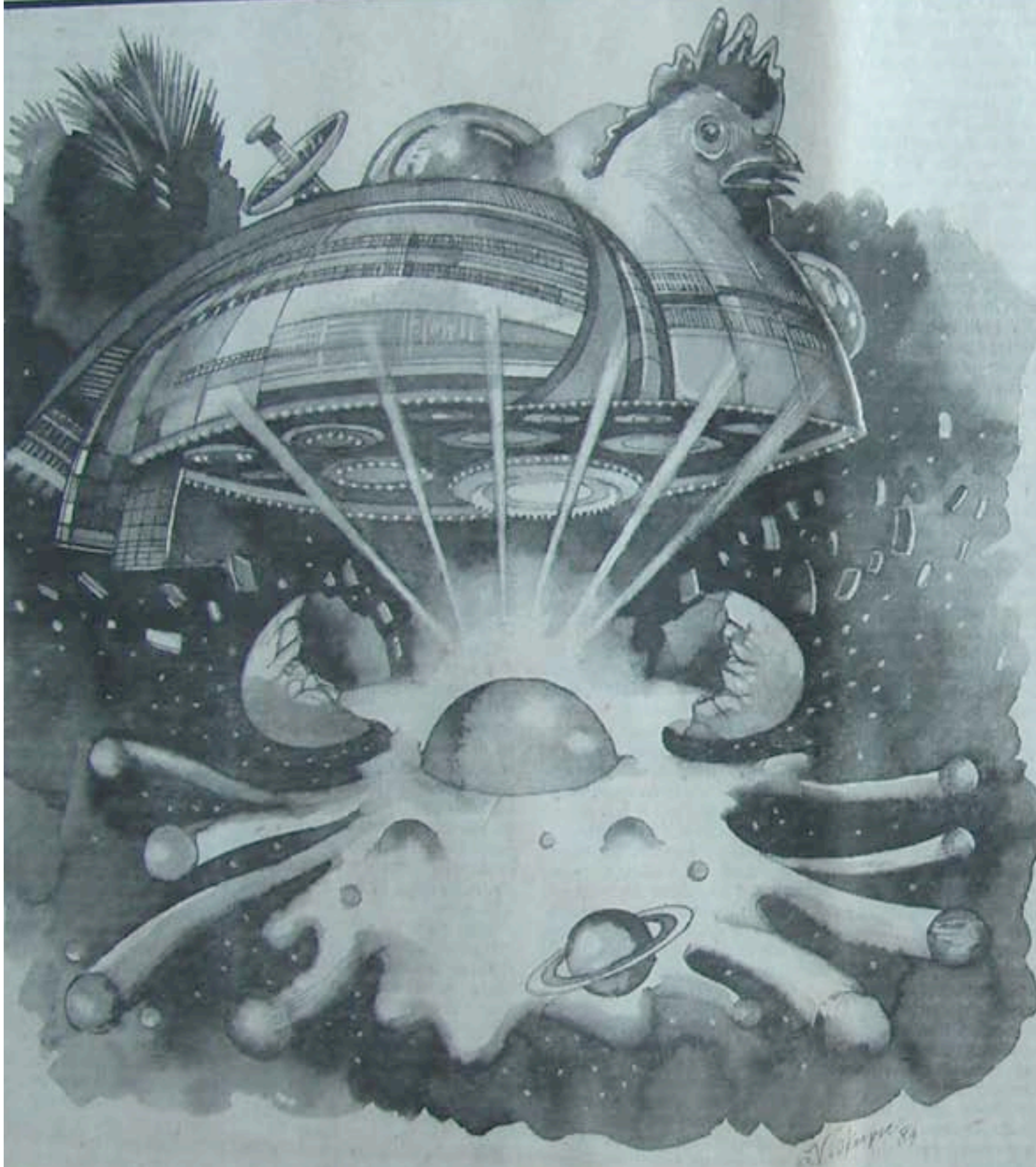
OUTLOOK

Commentary and Opinion



By Gary Viskupic for The Washington Post

The Cosmic Riddle: How Rocks and Stars Became Flesh and Blood

By Eugene F. Mallove

LIFE'S EMERGENCE from the dust of the universe must be counted the greatest wonder of nature. We are all starstuff. Every atom of our bodies was cooked in primordial nuclear fires or blasted from the innards of dying suns.

But how did our life get there? Did a supernatural Designer — outside space and time — breathe fire into senseless matter? Is life as we know it the inevitable product of the physical universe? These are questions that cannot yet be answered by science. But for the last 30 years, a scientific approach to the origin of life has dug up tantalizing clues and unleashed new controversy. Not only the *how* but the *where* of life's beginning is the focus of the scientific quest.

The consensus view of science is that life began in the oceans of chemical broth cooked up on the primitive Earth over 3.5 billion years ago. But there are stirrings of dissent among some theorists who, backed by the latest astronomical findings, place life's origin in comets, in tenuous clouds of matter in interstellar space or even on other distant worlds far removed from the Sun and its brood of planets.

There is overwhelming biological, geochemical and paleontological evidence that the course of life has followed an evolutionary path, sometimes gradually and other times in great spurts, since its inception on Earth. True, the mechanisms of biological evolution are still heatedly argued by scientists. But that life evolved to its present state from lower forms is as close to scientific fact as anything can be.

Yet the origin of the first living cell from which everything else evolved remains a deep mystery. We know more about the first milliseconds following the Big Bang that created the universe than we know about that.

We are far from certain even that "life as we know it" is the only type of "life" that may grace the cosmos. Our life is based on the element carbon. But there may be chemistries based on other elements — like the silicon that makes up sand — that could lead to replicating and information-processing "life."

Even more fantastic, perhaps other "life" inhabits niches totally alien to our convention wisdom — the hot surfaces of dense stars, the electromagnetic fields of interstellar space or, on cold planets, low-temperature crystalline networks yet unknown. We suffer terribly that we have but one example of life — Earthlife — with nothing to compare it to. If life is the inevitable offspring of matter, as seems likely to many scientists, the cosmos should be just teeming with life, and we will someday meet with fellow questers.

The weight of modern scientific opinion is that life started in the oceans of primitive Earth — a chance or inevitable outgrowth of a "soup" of chemicals. By radioactive dating of meteorites, scientists have determined the age of the solar system — about 4.6 billion years. The oldest rocks on the surface of the Earth are 3.8 billion years but underwent too much heating for any fossilized cellular life forms to be apparent.

See LIFE, C2, Col. 1

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How the Stars Gave Birth to Life

LIFE, From C1

But rocks 3.5 billion years old have the fossil remains of single-celled organisms. The startling conclusion: Life appeared on Earth about a billion years after the planet solidified, a small fraction of its age, a smaller fraction still of the 12- to 20-billion year age of the universe. How much less than that billion years it took to get to that very first cell may never be known, but it could have taken a surprisingly short time — several hundred million years or less.

The short time to the first cell is some indication that life starts readily on a suitable planet. On the other hand, the succeeding 3 billion years, through which the fossil record shows life remaining for the most part in one cell only, might indicate that complex multicellular life is harder coming. It was only 570 million years ago that life began an evolutionary explosion that led to today's great diversity of plants and animals in water, on land, in the air and just now — in space.

Life as we know it, basically, is composed of cells whose main characteristics are an ability to metabolize — exchange chemicals with their surroundings to get energy and material for their workings — and an ability to pass on information to succeeding generations of similar cells. The passing of information is the responsibility of nucleic acids within the cell — the DNA and RNA that are the repository of the genetic code.

We now have the first glimmerings of how these functions could have developed. The Russian and British biochemists, A.I. Oparin and J.B.S. Haldane, independently suggested in the 1920s that the primitive Earth did not have an oxygen atmosphere. They suggested that, rather, it had an atmosphere of gases such as hydrogen, methane, ammonia and carbon dioxide. Moreover, they postulated that this atmosphere might lead to the formation of primitive organic molecules.

It wasn't until 1953 that their suggestions were subjected to test, in what is now called the seminal Urey/Miller experiment. A graduate student, Stanley Miller, acting on a suggestion of his professor, Harold Urey, at the University of Chicago, set up a glass chamber into which methane, ammonia, hydrogen and water were introduced. He allowed a high-voltage electric spark to hit the mixture — such as lightning might on a new Earth. Within days he found in the chamber the building blocks of proteins — amino acids galore, plus other organic molecules.

In the same year, Francis Crick and James Watson finally unraveled the mystery of DNA, discovering that by a simple coding sequence of four so-called chemical "bases," complex genetic information could be stored and transferred — analogous to the way information is stored in a computer.

While the Urey-Miller and Watson-Crick developments were extraordinary, no living creature crawled out of a test tube. Biochemists attempting to illuminate how life might have formed are faced with a chicken and egg problem. DNA has the information required to make proteins — the building blocks of life consisting of chains of amino acids. But to make these proteins, enzymes are required, to catalyze the chemical reaction.

The problem is that enzymes themselves are proteins. So the question is how did enzymes originate before there were any enzymes? This is one of the most fundamental — but not the only — problem in discovering how life started. One thing seems certain: An enzyme could not have been built by accidentally agglomerating the right subunits together, even given an ocean much larger than Earth's and older than the age of the universe.

Some take biochemistry's failure to unravel the mystery of life's origin to be a sign that supernatural intervention or freak chance equivalent to it must be involved. But this is not the opinion of most biochemists, who do not really hope to create a cell from primitive molecules, but who, in the words of biochemist Richard E. Dickerson, have the "broad goal to arrive at an intellectually satisfying account of how living forms could have emerged step by step from inanimate matter on primitive Earth."

Biochemist Leslie Orgel graphically illuminates the source of our ignorance: "Imagine a professor, very long lived and a master of getting research grants, working in his lab for 100 years with 100 graduate students day and night, each of whom have 10 liters of various chemistry cooking continuously. That would only amount to 100,000 liter-years of effort. The primitive ocean of Earth with a billion years at its disposal had one with 29 zeros liter-years."

Perhaps in that ocean of Earth an original "naked" self-replicating molecule did arise which began to dominate the chemical stew. Unshielded from the surrounding chemicals, it is hard to imagine how it could preserve itself very long. With this problem in mind, some biochemists have experimented with creating primitive "cells" — mere pockets of chemical broth surrounded by a fatty coating. Whatever chemical innards these sacs came to nurture would not be in danger of being diluted to oblivion.

Some of these microspheres — about the size of real cells — have been infused with biochemicals to see how they behave. Wondrously, the fake cells acquire lifelike properties such as stability due to their primitive "metabolism" and an ability to divide producing "offspring." It is a very long leap to the first real cell, but each new experiment casts new light on what may have happened long ago.

What biochemists lack in understanding processes leading to the first cells is made up by expanding knowledge of what later led to the evolution explosion of multicelled organisms.

The first cells were "prokaryotes" — cells which did not have a central nucleus to contain their DNA. The fossil record shows that early versions of these cells are closely related to contemporary blue-green algae. These earliest cells had an "anaerobic" metabolism. That is, they got their energy without relying on an oxygen atmosphere, using a process akin to fermentation. In fact, for some of them, oxygen was a poison.

Some of these bacteria developed an ability to use sunlight to chemically store energy — a process called photosynthesis. Then, some cells began to tolerate the new oxygen poison, and to give it off into the atmosphere. This gradually created the massive amount of oxygen in the atmosphere that we now have.

This oxygen permitted an ozone (combination of three oxygen atoms) layer to form in the upper atmosphere which shut out ultraviolet radiation destructive to surface life. (Formerly, the radiation perhaps aided the formation of the chemical soup that preceded life.)

The period of having only cells without a nucleus lasted to 1.5 billion years ago, when the first "eukaryotes" appeared — cells with distinct nuclei containing their genetic material. Very strong evidence links the advent of cells with nuclei to a parasitic symbiosis between the earlier cells. The specialized units inside these new cells, such as the nucleus, may well have started as the simpler cells that took up residence within other simple, early cells.

The significance of these cells with nuclei is that they were the first organisms able to reproduce sexually. The earlier, simpler cells simply divided in half. Sexual reproduction — with its ability to more readily produce slightly altered forms in each generation — no doubt greatly speeded up evolution. Significantly, the greatest evolutionary expansion occurred shortly after the cells with nuclei appeared.

It has been said that "the price of sex was death," for in their simple splitting, cells eternally produce identical copies of themselves (except for chance mutations). They thus are the closest thing to immortal life. The deaths of eukaryotes and higher forms, however, continuously make room for new life.

As far back as Darwin, the "warm little pond" notion of life's origin has held sway. But what if that little pond were not on Earth? Could life have originated elsewhere? Does it matter? Since the Swedish chemist, Svante Arrhenius, proposed a theory of "panspermia" early in this century, these questions have refused to go away.

Arrhenius contended that spores of life could rise in the atmosphere of another planet, either in this solar system or around another star. Electrostatic forces might eject such spores from the atmosphere and the spores could be carried across interplantary or interstellar space to start life on other worlds. Perhaps life on Earth began this way.

Panspermia would not remove the problem of the biochemical origin of life, just change the site to another world at an earlier time. Doubt has been cast on the panspermia hypothesis by Carl Sagan and others, who claim that unshielded microbes couldn't survive ultraviolet, X-ray, proton and cosmic radiation of long space journeys in vacuum and minus-200 degree Centigrade cold.

The difficulties for natural panspermia are indeed formidable. A vast quantity of spores would have to emerge from another star system to have a good chance of reaching Earth — although just one spore would be sufficient in theory.

A more radical theory — deliberate or directed panspermia on the part of intelligent aliens — was proposed by Francis Crick and Leslie Orgel. This theory is much more difficult to dispute, since it is possible that an advanced race would have had the technology to seed primitive Earth with bacteria.

Whether there is reasonable motivation for this directed panspermia is an open question. Physicist Thomas Gold once suggested that an early landing expedition inadvertently contaminated Earth, uninspiring as a "space garbage" origin is.

Crick and Orgel are careful to say that they are putting forth the idea only as a theory which is *consistent* with the facts. But as evidence for directed panspermia, Crick and Orgel cite the universality of the genetic code on Earth. If the Earth was replete with warm little ponds, would not other forms of the code have arisen and persisted? They also point to other anomalous aspects of biochemistry. For example, the element molybdenum is an essential ingredient of life — yet it is a minute trace constituent of Earth's crust.

Pehaps the strongest reason to believe intentional seeding occurred is the rapid start that life achieved after Earth formed. A more ancient populated world could have recognized an incipient hospitable planet and acted to spread their heritage.

Life may not have arrived from space as fully formed microscopic organisms, but the chemical precursors of life might have come from interstellar space. Radio astronomers are today faced with a bewildering host of microwave signals from dozens of organic (carbon-based) molecules in space.

Some think that these organics might have been deposited on Earth in collisions with comets that have, in turn, wandered between the stars. The Murchison meteorite that landed in Australia in 1969 was found to have amino acids with properties clearly indicating that processes in space, not contamination by terrestrial life, formed them.

Astrophysicist Fred Hoyle and his colleague Chandra Wickramasinghe have startled the astronomical community with their theory that life is co-eternal with an infinitely-old universe. They start with the premise that it is impossible to imagine the chance aggregation of nucleic acids and associated enzymes required to build proteins. Hence, life in the universe is ordained by a "pre-existing intelligence" in their view. The consequences of this notion is that viral, bacterial, and even insect life is imagined to populate space. This life wafts down on planets and starts an evolutionary sequence which continues to be aided by interstellar viral influence.

They point to difficult-to-explain characteristics of earthly disease epidemics as evidence that viruses might come from space. Their theory is very much doubted. Their strongest evidence is that microfossils of bacteria appear to be contained in several meteorites.

Who is to say that "life" cannot have an entirely different form and exist in a radically different environment? Astronomer Frank Drake has suggested, for example, that life could be nuclear-based and inhabit the surface of superdense neutron stars. Instead of chemical reactions, neutron-star beings would employ much more rapid interactions of nuclear particles. These aliens would be unlike any life with which we are familiar, yet physicist Robert Forward has scientifically chronicled the evolution of an entire civilization of them in his dramatic science-fiction novel, "Dragon's Egg."

In the vast reaches of interstellar space, perhaps "beings" exist which make use of tenuous matter and electromagnetic fields.

Then there is speculative silicon-based life, life that would substitute silicon for carbon atoms, but which would have to exist at greatly elevated temperatures. The list of possibilities is endless.

We know that life has evolved at least once. Applying the often-stated tongue-in-cheek Fourth Law of Thermodynamics, "Anything that has happened can happen," we are led to suspect life's evolution elsewhere, though in what form and how frequently is uncertain.

The two Viking landers which inhabit Mars left us with a mystery after conducting their biology experiments in 1976. One test was positive for life, another check for the presence of organic molecules was negative. Attempts to explain the results by inorganic chemical reactions have not been satisfactory.

Saturn's moon, Titan, the only moon in the solar system with a substantial atmosphere, probably has an extensive ocean of liquid hydrocarbon organics. Jupiter's moon Europa is an ice-sheathed world that likely has a hidden liquid water ocean a few hundred meters below its cracked surface. What life forms may lurk in these deeps?

Albert Einstein once said that "the most incomprehensible thing about the universe is that it is comprehensible." Given the mystery of how "simple" matter becomes intricate life, one could well say that the most incomprehensible thing about the universe is that, through life, it attempts to comprehend itself.

The majestic spectacle of the universe coming to know itself through an evolutionary process is an inspiration to some and blasphemy to others. Scientists with a religious bent are generally more in awe of what they have already found in the record of the rocks, than of an instantaneous supernatural creation in which they cannot believe.

The record speaks of a profound order and, yes, a purpose in nature. Someday we may know for sure whether life was an inevitable child of the physical universe or a chance event almost unique to our small quarter. But the vote now in the halls of science is all on the side of inevitability.