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Carl Woese, Dick Young, and the roots of astrobiology

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Abbreviations: COSPAR, Committee on Space Research; DNA, deoxyribonucleic acid; ISSOL, The International Society for the Study of the Origin of Life; NASA, National Aeronautics and Space Administration; RNA, ribonucleic acid

The beginning of the space age in the late 1950s gave rise to innovative and interdisciplinary research concepts and perspectives, including the concept of "exobiology" as a way to approach the fundamental aspects of biology through a study of life outside of the Earth, if it existed. This concept was embodied by NASA into its formal Exobiology Program and into the philosophy of the program both before and after the *Viking* missions that were launched to Mars to search for signs of life in 1975. Due to both management flexibility and an acceptance of the interdisciplinary nature of the problem of "life in the universe," NASA program managers, and particularly Richard S Young who ran the Exobiology Program beginning 1967, have made some excellent investments in paradigm altering science of great use both on Earth and on future space missions. The work of Carl Woese is one such example, which has revolutionized our understanding of the microbial world and the relationships of all life on Earth.

It was 1960 (and I was 7 y old) when the concept of establishing universal principles in biology by "using the perspective of comparative biology on a cosmic scale" was advocated to a scientific audience for the first time since the first artificial satellite, *Sputnik*, had flown in 1957 (COSPAR, 1st International Space Science Symposium, Nice, France, January 1960). In an address published later in *Science*,[1] Nobelist Joshua Lederberg espoused the term "Exobiology" to describe the employment of this overall perspective in biology, and (among other things) advocated that an examination of the universal features of terrestrial life be accomplished, giving highest priority to the nucleic acids and how subtle differences in them lead to "all the variety of terrestrial life."

It was a heady time for biologists, who for the first time were beginning to trace and understand the DNA-encoded messages hinted at by Watson and Crick[2] in 1953, and tie them to the ordering of protein formation at the fundamental foundry of the cell—itself made up of protein and nucleic acids—the ribosome. New molecular tools were being developed, albeit slowly, to understand how the nucleic-acid genome was structured and how it might evolve over time, and with Lederberg's address the idea of finding life outside the Earth and understanding the structure, function, and evolution of its genome (and origins) seemed like a logical step for the burgeoning space programs of the world.

Be that as it may, there were a few obstacles, both practical and cultural. On the cultural side, there was a suspicion on the part of some that the US effort (read funding) for the space program would attract lower-quality science or tie biological research too closely to the military[3] and military aerospace medicine, or would be somehow tainted by the "gee whiz" aspects of NASA rocket science, and its public appeal. Then, too, the speculative aspects of a search for life elsewhere in the universe (and its costs) concerned some, perhaps most famously Harvard paleontologist George Gaylord Simpson who complained,[4] "there is even recognition of a new science of extraterrestrial life, sometimes called exobiology—a curious development in view of the fact that this 'science' has yet to demonstrate that its subject matter exists!" Given that one of his conclusions was that "there probably are forms of life on other planetary systems somewhere in the universe, but if so it is unlikely that we can learn anything whatever about them, even as to the bare fact of their real existence,"[4] his approach could hardly be called inspired, but concerns about funding likely underlay much of his rhetoric. For example, he also complained that "another curious fact is that a large proportion of those now discussing this biological subject are not biologists," and that "evolutionary biologists and systematists have rarely been consulted and have volunteered little to the discussion."[4]

Small wonder!

That was about to change; although that sort of concern by senior academics was a powerful force, sometimes in the open but often hidden within faculty tenure discussions or the confidential peer review of grant applications.

On the practical side, both the study of "life as we know it" and the study of "life in the universe" were limited by the tools available. While it was then established that DNA and RNA carried an evolvable code for the proteins that would make up an organism, it was inordinately time-consuming to read the coded sequence of all but the shortest nucleic acid strands. And while one could (and did) develop an experiment that could conceivably

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Figure 1. During the ISSOL meeting in Barcelona in 1993, an excursion was taken to the Codorniu Winery nearby. This image was taken of Richard S Young, Donald DeVincenzi, John Rummel, and Michael Meyer to celebrate Rummel's having turned over the Exobiology Program to Meyer, and thus, it is signed by "The Dynasty" of then-living Exobiology managers.

culture Mars microorganisms in Earth-like conditions, on Mars,[5] the knowledge of how unlikely we are to detect even Earth microbes through culture methods was not generally appreciated at the time. In fact, it was that realization that may be one of the most appreciated results of NASA's investment in exobiology.

Where NASA and fundamental biological science have had their most productive encounter has certainly been within NASA efforts on exobiology and the diversified astrobiology programs (including exobiology) that were introduced in the late 1990s (e.g., ref. 6). Whereas NASA's exobiology efforts had started out with a majority focus on spaceflight instruments and issues (e.g., spacecraft sterilization),[7] in 1967 when Richard S ("Dick") Young took over the Exobiology (occasionally "Planetary Biology") Program at NASA Headquarters, there was a large focus on the upcoming Viking missions to Mars, but that did not limit Young's belief that the program had to tackle the fundamental aspects of Lederberg's exobiology—to include an examination of the fundamental biological principles demonstrated by life on Earth—if it were to serve both the scientific and spaceflight demands of the future.

To organize the expanded effort, Young arranged a series of meetings on the origin of life and exobiology,[8] participated in the formation of the International Society for the Study of the Origin of Life (ISSOL),[9] and Young himself actively attended those meetings as well as others held by international groups. During this time he not only discovered and promoted some outstanding talent, but he laid the groundwork for the program to continue to contribute to NASA and the scientific community's goals after the Viking missions (launched in 1975) were over, when its goals could be described by then-manager, Donald DeVincenzi (1984) as:

"The goal of NASA's Exobiology Program is to understand the origin, evolution, and distribution of life, and life-related molecules, on Earth and throughout the universe."[10]

A tall order, but one has to start someplace. This same, basic philosophy guided the program in one form or another from the time that Dick Young started running it, and certainly through its incorporation into an expanded Astrobiology effort, with an overlapping set of goals, at the end of the 20th century. See **Figure 1**.

What NASA was able to provide with the Exobiology Program was not only a broadly defined charter, and an approach that was inherently interdisciplinary, but management flexibility as well. NASA's rapid growth in both the lunar-oriented Gemini and Apollo programs came with a corresponding growth in its science apparatus that supported both "manned" (as they used to say) and unmanned missions, and in order to implement its programs successfully NASA placed a fair amount of discretion in the hands of its science managers, like Dick Young. While NASA was committed to the principle of peer review as the way to assess the science merit of a proposal, science managers were able to cite other benefits of a proposal if the strict merit review did not rank it highly. In this respect, factors like programmatic relevance and the benefits of a risky proposal being successful could be factored into the overall funding decision.

In my experience, that, and a commitment to scientific discovery and not to favored outcomes, made all the difference between having good science in the program or great science. It does put the onus directly on the program manager's shoulders and of course a successful investment requires the proposal's investigators to live up to their promise (both literally and figuratively), but it can make a huge difference when scientific paradigms are being questioned by new data.

As it happens, Dick Young was a great investor.

Having funded Lynn Margulis to continue her work in establishing the serial endosymbiotic theory (e.g., ref. 11) beginning in 1971,[12] it is clear that Young did not tie his investment strategy to the academic position of the principal investigator or the immediate impact of the idea on space missions. Rather than the science serving the missions, he operated on the concept that the science should be served by the missions, and that fundamental knowledge obtained on Earth was required to make the best use of the much costlier missions that NASA might fly to investigate possible biological systems elsewhere. Into this scheme of things, investigations into the origin of life on Earth and the early evolution of life, as seen both in the rock record and in the record found in living organisms, today, fit neatly—and it was the record found in living organisms that Carl Woese was investigating.

It is recorded[13] that Young, having heard of his promising (if difficult) research plan, approached Woese during a meeting on "The Origin of Life" in Paris in April 1973, and suggested that Carl apply for funding from NASA Exobiology—and that Young funded that first proposal as well as subsequent applications. And as it happened, Young and NASA didn't have to wait very long for an excellent result (cf., ref. 14)—both the reshaping of our understanding of the relatedness of all life on Earth, and the proof-of-concept of an approach and toolkit that has gone on to revolutionize our ability to work with, and understand the microbial world.

And if we get further down into Mars and find (as Norm Pace once put it to me) that Mars and Earth life are "all rooted in the same big tree," then we will have everything we need to study Mars life, as well.

If not, then we will really learn something about the fundamental characteristics of life, making full use of the Lederberg legacy of exobiology.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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