**Rare Earth: Why Complex Life is Uncommon in the Universe** by Peter D. Ward and Donald Brownlee. New York: Copernicus/Springer Verlag, 2000.

**Here Be Dragons: The Scientific Quest for Extraterrestrial Life** by David Koerner and Simon LeVay. New York: Oxford University Press, 2000.

**Life Everywhere: The Maverick Science of Astrobiology** by David Darling. New York: Basic Books, 2001.

Interest in the existence of extraterrestrial life continues unabated at both the public and professional levels. On Earth, discoveries of life in extreme environments are now commonplace, while theories of the origin of life on our home planet are debated in increasingly sophisticated detail. In our solar system the analysis of Martian meteorite ALH 84001 has given rise to five years of contentious but enlightening debate, and the possibility of water on several Jovian moons has fueled speculation of life outside the traditional "habitable zone" of our Sun. Extrasolar planets continue to be discovered at a steady rate (60 have been announced to date, with the nature of some still in contention), although Earth-size planets still elude detection around normal stars. In recent years the Search for Extraterrestrial Intelligence (SETI) has expanded its approach from radio to optical regions of spectrum, and entire arrays of radio telescopes are being built around the country to research life's past, present, and future in the universe (though by curious Congressional mandate, NASA has not funded SETI research since 1993). In the last year not just one, but two respected publishers have announced plans to launch astrobiology journals. And the popular media excitedly reports the latest results to an eager public.

All of this is no surprise. The outcome of the astrobiology endeavor, after all, bears on our place in the universe, a subject of perennial interest. A universe full of life—what I have termed elsewhere a "Biological Universe"—is a world view of its own with profound implications. Increasingly, the social, philosophical and theological promise and problems of astrobiological success are debated. A good part of science fiction literature, as well as the extraterrestrial hypothesis of UFOs, may be seen as ways of working out this world view in popular culture. The scientific arguments are passionate and full of interest precisely because of these high stakes. That the subject is at the very limits of science makes it even more interesting, as philosophy, metaphysics and even theology mingle with empiricism in ways not always obvious to the public, or even to scientists themselves.

The three books under review come to quite different conclusions regarding this world view, and are a vivid illustration of diverse interpretation of the same evidence. As implied by its title, the most optimistic of the books is Darling's *Life Everywhere,* which states up front that "almost beyond doubt, life exists elsewhere." The author, a writer with a PhD in astronomy, is clearly enamored of his subject, and indeed it is difficult not to be. *Here Be Dragons* is also an optimistic assessment of the biological universe. The authors, an as-

tronomer and a biologist, describe themselves as "professional skeptics" who admit there is no direct evidence for life beyond Earth, doubt that ETI has visited Earth, and admit the possibility that we are alone. Nevertheless, they venture into the "rough seas of speculation" and conclude in the end that life is likely: "human surely not, but maybe someone wiser."

Both books are written at a similar "intelligent layman" level, and cover much the same ground: the latest theories and experiments on the origin of life, the search for life in the solar system, and the search for extrasolar planets. Curiously, Darling says very little about SETI, perhaps because it is not part of astrobiology as currently programmatically defined at NASA. But both touch on the relevance of the debate of concepts like artificial life and Gaia, with Koerner and LeVay sensibly remarking that they dislike the "New-Agey" branch of Gaia expressed in books such as *Gaia* and *God: An Ecofeminist Theology of Earth Healing.* Although both books are optimistic with respect to a biological universe, Koerner and LeVay are more cautious in seeing the underlying assumptions that enter into their conclusions.

*Rare Earth* is by far the most skeptical of the three books and is itself a rarity: a book that concludes that, while microbial life may be abundant in the universe, intelligent life is rare, resulting in what might be called a weak, rather than a strong, biological universe. Although the authors may not know it, theirs is the type of book that comes along about every 50 years or so. In 1853 the British philosopher William Whewell bucked prevailing opinion by arguing in *Of the Plurality of Worlds* that the locations where life might flourish in the universe are very restricted. In 1903 A. R. Wallace, the cofounder with Darwin of the theory of evolution by natural selection, updated the argument in *Man's Place in the Universe: A Study of the Results of Scientific Research in Relation to the Unity and Plurality of Worlds.* Wallace used the latest research in astronomy and biology to come to the distinctly non-Darwinian conclusion that "our position in the material universe is special and probably unique, and …it is such as to lend support to the view, held by many great thinkers and writers today, that the supreme end and purpose of this vast universe was the production and development of the living soul in the perishable body of man." Despite the optimism generated by Lowell and the canals of Mars, by 1940 British astronomer Royal Sir Harold Spencer Jones was almost as pessimistic as Wallace in *Life on Other Worlds,* particularly in light of the Jeans-Jeffreys hypothesis of the rarity of planet formation. Once that hypothesis was discarded, later editions of Spencer Jones were more optimistic, and since the 1950s and 1960s, with the writings of Harlow Shapley, Carl Sagan, Frank Drake, and a host of others, optimism for a Biological Universe has been on the rise. Thus the shock and media attention when Ward and Brownlee pronounced in *Rare Earth* that ETI might be rare.

Unbeknownst to Ward and Brownlee (since they do not seem to be aware of Wallace's book), they repeat many of Wallace's century-old arguments regarding what is essential to a habitable planet and complex life: the distance of the planet from its Sun, the right planetary mass, the tilt of its axis, the right

amount of ocean, the right atmosphere, the essential biogenic elements, biological evolution, the right position in the galaxy, and so on. They add new arguments based on recent research, including the need for a large moon to stabilize the Earth's tilt; no global sterilizing impacts after an initial period, perhaps necessitating a Jupiter-like giant planet to clear out comets and asteroids; and the need for plate tectonics as a regulator of global climate and promoter of biodiversity. Ward and Brownlee add these elements to the famous Drake Equation for the number of technological civilizations in the Galaxy, resulting in a "Rare Earth Equation."

Yet, what have Ward and Brownlee proven? They are careful at times to couch their discussion in terms of the Rare Earth "hypothesis." With that I have no problem. But after stating that their additional parameters in the Rare Earth Equation "are known only in the sketchiest detail," they go on to conclude that "it is our contention that any strong signal can be perceived, even when only sparse data are available. To us, the signal is so strong that even at this time, it appears that Earth indeed may be extraordinarily rare" (p. 275). With this declaration, they transform hypothesis to highly probable fact, reflected in the subtitle of their book "why complex life is uncommon" rather than "why complex life may be uncommon" in the universe. Surely the sweeping claim that the Earth is rare in the universe is extraordinary and breathtaking in its scope, yet the evidence does not match the claim any more than did Wallace's a century ago. Surely Sagan's dictum that extraordinary claims require extraordinary evidence applies to negative claims as well as positive ones. For each Rare Earth argument there is a counterargument; Darling provides some of them in his book. Thus Ward and Brownlee's argument seems to me no more conclusive than that of Frank Tipler, who claimed a decade ago he had proven from the "Where are They?" Fermi Paradox that extraterrestrials do not exist, since they should have arrived on Earth long ago given the timescale of the universe. Tipler's conclusion that all SETI programs are a waste of money impressed politicians, but not most scientists. I expect "Rare Earth" as fact, rather than as hypothesis, will have the same reception.

*Rare Earth* is a book that needed to be written. Science must look at all sides of the debate in all the detail the data will merit. But I cannot help comparing Ward and Brownlee's method and conclusions to those of Wallace, also a careful scientist who used the latest evidence from biology and astronomy to conclude not only that Earth harbored the single case of intelligent life in the universe, but also that it was very near the center of the universe! Ward and Brownlee seem to have proven that complex life on Earth does not, or should not, exist. Yet, here we are! This leaves the reader at least three options: (1) the Earth is the result of miraculous intervention; (2) the Earth is extremely rare; or (3) we do not yet have enough data to warrant such a conclusion. I come down firmly in favor of option (3). We have indeed learned a great deal in the century since Wallace, but not enough to make the sweeping claim of Rare Earth. Moreover, while Ward and Brownlee avoid some of Wallace's more obvious metaphysical assumptions, they undoubtedly have introduced some of

their own. Darling, whose book is recent enough to include a chapter on "Rare Earths and Hidden Agendas," turns up the interesting fact (p. 111) that an astronomer who had significant input into the Rare Earth arguments (not one of the authors) has also written extensively on intelligent design in the universe and is an active proponent for such design. Anthropocentric thinking and metaphysics in science are not as dead as we might think.

The meaning and impact of the Rare Earth hypothesis also hinges on the definition of "rare." With billions of Sun-like stars in the galaxy and billions of galaxies, even after paring down by the Rare Earth Equation, surely some planets will have conditions similar to Earth. I would find 100 civilizations in the Galaxy only slightly less interesting than 1000. Moreover, while other planets may not be similar to the Earth, surely in the wake of recent discoveries of life in extreme environments at the microbial level, we should be open to the possibility that intelligence may have found different paths than on Earth. There may be as many paths to intelligence as to microbial life. Earth has been only a finite laboratory, and one can argue how many times intelligence has arisen even here.

In the end, the jury is still out. We do not yet know whether we live in the strong biological universe of Darling, Koerner and LeVay, or the weak biological universe of Ward and Brownlee. Or, for that matter, in a purely physical universe in which we are the great exception. Most scientists understand this, but one can only hope that the book does not have the same effect as Tipler's work, in which he pushed the Fermi paradox to the extreme conclusion that no further search was necessary. This claim, while flying in the face of empirical methods of science, nevertheless aided Congressional efforts to bring federal funding for SETI to a screeching halt in 1993, amidst irrelevant ridicule about UFOs and Martians. Even with the outrageous "is," rather than "maybe," in the subtitle of *Rare Earth,* politicians should realize that the authors support the current thrust of astrobiology; in fact their home institution at the University of Washington is a pioneer in the field.

Even the discovery of microbial life would be the greatest event in the history of science, allowing terrestrials at least to glimpse the principles of a more generalized biology if informed by an independent second genesis. Meanwhile, I predict that both astrobiology and the search for ETI will have careers long past the 21st century and continue in the vanguard of the long and venerable tradition of the search for ourselves. Koerner and LeVay explicitly state the optional underlying assumptions of the search: the Copernican-based "principle of mediocrity" that there is nothing special about our view of the universe, or the belief that we do have a privileged view, embodied in the anthropic principle. Alas, we cannot know which of these metaphysical principles is true—until we look.

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