

Chapter 2*



Cosmic Evolution

History, Culture, and Human Destiny

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During the course of the 20th century, a powerful new idea gradually entered human consciousness and culture: that we are part of a cosmos billions of years old and billions of light years in extent; that all parts of this cosmos are interconnected and evolving; and that the stories of our galaxy, our solar system, our planet, and ourselves are part and parcel of the ultimate master narrative of the universe, a story we now collectively term “cosmic evolution.” Even as in some quarters of popular culture, heated debate continues over Darwinian evolution 150 years after the idea was published, over the last 50 years the much more encompassing idea that Carl Sagan embodied in the phrase “the cosmic connection” has become more and more a part of our daily lives, and will even more in the future as our cosmic consciousness increases.¹

Cosmic evolution provides the proper universal context for biological evolution, revealing that the latter is only a small part of the bigger picture, in which everything is evolving, including life and culture. The more we know about science, the more we know culture and cosmos are connected, to such an extent that we can now see that the cosmos is inextricably intertwined with human destiny, both in the short term and the long-term, impinging on (and arguably essential to) questions normally reserved for religion and philosophy. It is the purpose of this chapter to uncover the historical evolution

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of this new understanding of the cosmos, describe the effects on culture so far, and outline the potentially far-reaching impact on the future of humanity.

Cosmic Evolution and History

The idea of cosmic evolution implies a continuous evolution of the constituent parts of the cosmos from its origins to the present. Planetary evolution, stellar evolution, and the evolution of galaxies could in theory be seen as distinct subjects in which one component evolves but not the other, and in which the parts have no mutual relationships. Indeed, in the first half of the 20th century scientists treated the evolution of planets, stars, and galaxies for the most part as distinct subjects, and historians of science still tend to do so.² But the amazing and stunning idea that overarches these separate histories is that the entire universe is evolving, that all of its parts are connected and interact, and that this evolution applies not only to inert matter, but also to life, intelligence, and culture. Physical, biological, and cultural evolution is the essence of the universe.³ This overarching idea is what is called cosmic evolution, and the idea has itself evolved to the extent that some modern scientists even talk of a cosmic ecology the “life of the cosmos” and the “natural selection” of universes.⁴

Although the question of extraterrestrial life is very old, the concept of a full-blown cosmic evolution—the connected evolution of planets, stars, galaxies, *and* life on Earth and beyond—is much younger. As historian Michael Crowe has shown in his study of the plurality of worlds debate, in the 19th century a combination of ideas—the French mathematician Pierre Simon Laplace’s “nebular hypothesis” for the origin of the solar system; the British naturalist Robert Chamber’s application of evolution to other worlds; and Darwinian evolution on this world—gave rise to the first tentative expressions of parts of this world view. The philosophy of Herbert Spencer extended it to the evolution of society, although not to extraterrestrial life or society. But some Spencerians, notably Harvard philosopher John Fiske in his *Outlines of a Cosmic Philosophy Based on the Doctrine of Evolution* (1875), did extend evolutionary principles to life on other planets.⁵

Neither astronomers nor biologists tended to embrace such a broad philosophical, and empirically unsupported, concept as full-blown cosmic evolution. Influenced by Darwin, 19th century astronomers and popularizers did occasionally propound the rudiments of the idea. In England, Richard A. Proctor proposed an evolutionary view in which all planets would attain life in due time. In France, Camille Flammarion argued that life began by spontaneous generation, evolved via natural selection by adaptation to its environment,

and was ruled by survival of the fittest wherever it was found in the universe. In this scheme of cosmic evolution, anthropocentrism was banished; Earth was not unique, and humans were in no sense the highest form of life. Thus were the general outlines of the idea of cosmic evolution spread to the populace, not only by these forerunners of Carl Sagan, but (as historian Bernard Lightman has shown) by a variety of Victorian popularizers of science.⁶

But such a set of general ideas is a long way from a research program. In the first half century of the post-Darwinian world, cosmic evolution did *not* find fertile ground among astronomers who were hard-pressed to find evidence for it. Spectroscopy, which displayed the distinct “fingerprints” of each of the chemical elements, did reveal to astronomers that those same elements were found in the terrestrial and celestial realms. This confirmed the widely assumed idea of “uniformity of nature,” that both nature’s laws and its materials were everywhere the same. Astronomers recognized and advocated parts of cosmic evolution, as in William Herschel’s ruminations on the classification of nebulae, the British astrophysicist Norman Lockyer’s work on the evolution of the elements, or the American astronomer George Ellery Hale’s *Study of Stellar Evolution* (1908). In their published writings, however, Hale and his colleagues stuck very much to the techniques for studying the evolution of the physical universe. Even Percival Lowell’s *Evolution of Worlds* (1909) spoke of the evolution of the physical universe, not a “biological universe” full of life, his arguments for Martian canals built by an alien intelligence notwithstanding. Although Lowell was a Spencerian, had been influenced by Fiske at Harvard, and had addressed his graduating class on “the nebular hypothesis” two years after Fiske’s *Cosmic Philosophy* (1874), he did not apply the idea of advanced civilizations to the universe at large.⁷

Even in the first half of the 20th century, astronomers had to be content with the uniformity of nature argument confirmed by spectroscopy. In an article in *Science* in 1920, the American astronomer W. W. Campbell (a great opponent of Lowell’s canalled Mars) enunciated exactly this general idea of widespread life via the uniformity of nature argument, “If there is a unity of materials, unity of laws governing those materials throughout the universe, why may we not speculate somewhat confidently upon life universal?” he asked. He even spoke of “other stellar systems . . . with degrees of intelligence and civilization from which we could learn much, and with which we could sympathize.”⁸

That was about all the astronomers of the time could say. As Helge Kragh concluded in his history of the Big Bang cosmology, “during the nineteenth century the static clockwork universe of Newtonian mechanics was replaced

with an evolutionary worldview. It now became accepted that the world has not always been the same, but is the result of a natural evolution from some previous state probably very different from the present one. Because of the evolution of the world, the future is different from the past – the universe acquired a history.” But the 19th century went only so far: “The Victorian conception of the universe was, in a sense, evolutionary, but the evolution was restricted to the constituents of the universe and did not, as in the world models of the 20th century, cover the universe in its entirety.”⁹

For the most part, biologists were also reluctant cosmic evolutionists even at the beginning of the 20th century. The British naturalist Alfred Russel Wallace, cofounder with Darwin of the theory of natural selection, wrote in 1903 that “[o]ur 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.” While he believed in a modicum of physical evolution in his small solar system-centric universe, he concluded that intelligence beyond Earth was highly improbable, calculating the physical, cosmic, and evolutionary improbabilities against the evolution of an equivalent moral or intellectual being to man, on any other planet, as a hundred million million to one. Clearly, for this pioneer in evolution by natural selection there was no cosmic evolution in its fullest sense, no biological universe.¹⁰

Similarly, Lawrence J. Henderson, a professor of biological chemistry at Harvard, wrote 10 years after Wallace, “[t]here is . . . one scientific conclusion which I wish to put forward as a positive statement and, I trust, fruitful outcome of the present investigation. The properties of matter and the course of cosmic evolution are now seen to be intimately related to the structure of the living being and to its activities; they become, therefore, far more important in biology than has been previously suspected. For the whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric.” Clearly, Henderson grasped essential elements of cosmic evolution, used its terminology, and believed his research into the fitness of the environment pointed in that direction. Yet, although he had a productive career at Harvard until his death in 1942, Henderson never enunciated a full-blown concept of cosmic evolution, nor did any of his astronomical colleagues.¹¹

Henderson’s idea of a biologically robust cosmic evolution in 1913 was largely stillborn; perhaps it was in part because just a few years later the British astronomer James Jeans’s theory of the formation of planetary systems by close

stellar encounters convinced the public, and most scientists, that planetary systems were extremely rare. This idea remained entrenched until the mid-1940s. Without planetary systems, cosmic evolution was stymied at the level of the innumerable stars, well short of the biological universe. In the absence of evidence, cosmic evolution was left to science fiction writers like Olaf Stapledon, whose *Last and First Men* and *Star Maker* novels in the 1930s embraced it in colorful terms. But Henderson had caught the essence of a great idea—that life and the material universe were closely linked, a fundamental tenet of cosmic evolution that would lay dormant for almost a half century.

The humble and sporadic origins of the idea of cosmic evolution demonstrate that it did not have to become what is now the leading overarching principle of 20th century astronomy. But it did, helped along by the Big Bang cosmology featuring a universe with a beginning slowly unfolding over time. The history of the Big Bang cosmology therefore parallels to some extent the history of cosmic evolution in its grandest sense, and Edwin Hubble's empirical observations of galaxies consistent with the concept of an expanding universe added a further dimension to the new world view.¹² Almost all astronomers today view cosmic evolution as a continuous story from the Big Bang to the evolution of intelligence, accepting as proven the evolution of the physical universe, while leaving open the still unproven question of the biological universe, whose sole known exemplar remains the planet Earth. The central question remains how far cosmic evolution commonly proceeds. Does it end with the evolution of matter, the evolution of life, the evolution of intelligence, or the evolution of culture? Today, by contrast with 1950, cosmic evolution is the guiding conceptual scheme for a substantial research program.

When and how did astronomers and biologists come to believe in cosmic evolution as a guiding principle for their work, and how did it become a serious research program? In her pioneering book, *Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology*, historian Betty Smocovitis has emphasized that with the rise of the modern synthesis in biology, by midcentury evolution had become a unifying theme for biology, with Julian Huxley and others also extolling its place in cosmic evolution. By the 1940s, Smocovitis wrote, “cosmic, galactic, stellar, planetary, chemical, organic evolution and cultural evolution emerged as a continuum in a ‘unified’ evolutionary cosmology.”¹³ But it was only in the 1950s and 1960s that the cognitive elements—planetary science, planetary systems science, origin of life studies, and the Search for Extraterrestrial Intelligence (SETI)—combined to form a robust theory of cosmic evolution, as well as to provide an increasing amount of evidence for it. Only then, and increasingly thereafter, were serious claims

made for disciplinary status for fields known as exobiology, astrobiology, and bioastronomy—the biological universe component of cosmic evolution. And only then did government funding become available, as the search for life became one of the prime goals of space science, and cosmic evolution became public policy.

We have already hinted at why this coalescence had not happened earlier, Spencerian philosophy and the ideas of Flammarion, Proctor, and Henderson notwithstanding. Although the idea of the physical evolution of planets and biological evolution of life on those planets in our solar system had been around for a while—and even some evidence in the form of seasonal changes and spectroscopic evidence of vegetation on Mars—not until the space program did the technology become available, resulting in large amounts of government funding poured into planetary science so that these tentative conclusions could be further explored. Moreover, if evolution was truly to be conceived as a cosmic phenomenon, planetary systems outside our solar system were essential. Only in the 1940s, when the nebular hypothesis came back into vogue, could an abundance of planetary systems once again be postulated. During a 15-year period from 1943 to 1958, the commonly accepted frequency of planetary systems in the galaxy went from 100 to one billion, a difference of seven orders of magnitude. The turnaround involved many arguments, from the observations of a few possible planetary companions in 1943, to binary star statistics, the nebular hypothesis, and stellar rotation rates. Helping matters along was the dean of American astronomers, Henry Norris Russell, whose 1943 *Scientific American* article “Anthropocentrism’s Demise” enthusiastically embraced numerous planetary systems based on just a few observations by Kaj Strand and others. By 1963, the American astronomer Peter van de Kamp announced his discovery of a planet around Barnard’s star, and the planet chase was on, to be truly successful only at the end of the century.¹⁴

Thus was one more step in cosmic evolution made plausible by midcentury, even though it was a premature and optimistic idea, since only in 1995 were the first planets found around Sun-like stars, and those were gas giants like Jupiter. But what about life? That further step awaited developments in biochemistry, in particular the Oparin-Haldane theory of chemical evolution for the origin of life. The first paper on the origins of life by the Russian biochemist Aleksandr Ivanovich Oparin was written in 1924, elaborated in the 1936 book, *Origin of Life*, and reached the English world in a 1938 translation. By that time the British geneticist and biochemist J. B. S. Haldane had provided a brief independent account of the origin of life similar to Oparin’s chemical theory. By 1940, when the British Astronomer Royal, Sir Harold

Spencer Jones, wrote *Life on Other Worlds*, he remarked that “It seems reasonable to suppose that whenever in the Universe the proper conditions arise, life must inevitably come in to existence.”¹⁵

The contingency or necessity of life would be one of the great scientific and philosophical questions of cosmic evolution, but in any case the Oparin-Haldane chemical theory of origin of life provided a basis for experimentation, beginning with the famous experiment of Stanley Miller and Harold Urey in 1953, in which amino acids—the building blocks of proteins and life—were synthesized under possible primitive Earth conditions. By the mid-1950s, another step of cosmic evolution was coming into focus—the possibility of primitive life. Again, the optimism was premature, but the point is that it set off numerous experiments around the world to verify another step in cosmic evolution. Already in 1954, Harvard biochemist George Wald proclaimed the Oparin-Haldane process a natural and inevitable event, not just on our planet, but on any planet similar to ours in size and temperature. By 1956, Oparin had teamed with Russian astronomer V. Fesenkov to write *Life in the Universe*, which expressed the same view of the inevitability of life as had Wald.¹⁶

What remained was the possible evolution of intelligence in the universe. Although hampered by a lack of understanding of how this had happened on Earth, discussion of the evolution of intelligence in the universe was spurred on by the famous paper by the American physicists Giuseppe Cocconi and Philip Morrison in *Nature* in 1959. “Searching for Interstellar Communications,” showed how the detection of radio transmissions was feasible with radio telescope technology already in hand. In the following year astronomer Frank Drake, a recent Harvard graduate, undertook just such a project (Ozma) at the National Radio Astronomy Observatory (NRAO), ushering in a series of attempts around the world to detect such transmissions. And in 1961, Drake, supported by NRAO director Otto Struve, convened the first conference on interstellar communication at Green Bank, West Virginia. Although a small conference attended by only 11 people including Struve, representatives were present from astronomy, biology, and physics, already hinting at the interdisciplinary nature of the task.¹⁷ Thus by 1961, the elements of the full-blown cosmic evolution debate were in place.

It was at the Green Bank meeting that the now-famous Drake Equation was first formulated. The equation $N = R_* \times f_p \times n_e \times f_i \times f_c \times L$ —purporting to estimate the number (N) of technological civilizations in the galaxy—eventually became the icon of cosmic evolution, showing in one compact equation not only the astronomical and biological aspects of cosmic evolution, but also

its cultural aspects. The first three terms represented the number of stars in the galaxy that had formed planets with environments suitable for life; the second two terms narrow the number to those on which life and intelligence actually develop; and the final two represent radio communicative civilizations. “L,” representing the lifetime of a technological civilization, embodied the success or failure of cultural evolution. Unfortunately, depending on who assigned values to the parameters of the equation, it yielded numbers ranging from one (Earth) to many millions of technological civilizations in the galaxy. Drake and most others in the field recognized then, and recognize even now almost 50 years later, that this equation is a way of organizing our ignorance. At the same time, progress has been made on at least one of its parameters; the fraction of stars with planets (f_p) is now known to be between 5 and 10 percent for gas giant planets around solar type stars.

The adoption of cosmic evolution was by no means solely a Western phenomenon. On the occasion of the fifth anniversary of Sputnik, Soviet radio astronomer Joseph Shklovskii wrote *Universe, Life, Mind* (1962). When elaborated and published in 1966 as *Intelligent Life in the Universe* by Carl Sagan, it became the bible for cosmic evolutionists interested in the search for life. Nor was Shklovskii’s book an isolated instance of Russian interest. As early as 1964, the Russians convened their own meetings on extraterrestrial civilizations, funded their own observing programs, and published extensively on the subject.¹⁸

Thus, cosmic biological evolution first had the potential to become a research program in the early 1960s when its cognitive elements had developed enough to become experimental and observational sciences, and when the researchers in these disciplines first realized they held the key to a larger problem that could not be resolved by any one part, but only by all of them working together. At first this was a very small number of researchers, but it has expanded greatly over the last 40 years, especially under NASA patronage. The idea was effectively spread beyond the scientific community by a variety of astronomers. As early as 1958 cosmic evolution was being popularized by Harvard astronomer Harlow Shapley in *Of Stars and Men*; and Shapley used it thereafter in many of his astronomical writings emphasizing its impact on culture.¹⁹ The idea was spread much more by Sagan’s *Cosmos* (1980), Eric Chaisson’s works beginning with *Cosmic Dawn: The Origins of Matter and Life* (1981), and in France by Hubert Reeves *Patience dans l’azur: L’évolution cosmique* (1981), among others.²⁰ By the end of the century cosmic evolution was viewed as playing out on an incomparably larger stage than conceived by A. R. Wallace a century ago.

The catalyst for the unified research program of cosmic evolution—and for the birth of a new scientific discipline—was the Space Age. No one would claim that a field of extraterrestrial life studies, or cosmic evolution, existed in the first half of the 20th century. Even by 1955, when Otto Struve pondered the use of the word “astrobiology” to describe the broad study of life beyond Earth, he explicitly decided against a new discipline: “[t]he time is probably not yet ripe to recognize such a completely new discipline within the framework of astronomy. The basic facts of the origin of life on Earth are still vague and uncertain; and our knowledge of the physical conditions on Venus and Mars is insufficient to give us a reliable background for answering the question” of life on other worlds. But the imminent birth of “exobiology” was palpable in 1960 when Joshua Lederberg coined the term and set forth an ambitious but practical agenda based on space exploration in his article in *Science* “Exobiology: Experimental Approaches to Life Beyond the Earth.” Over the next 20 years numerous such proclamations of a new discipline were made. By 1979, NASA’s SETI chief John Billingham wrote that “over the past twenty years, there has emerged a new direction in science, that of the study of life outside the Earth, or exobiology. Stimulated by the advent of space programs, this fledgling science has now evolved to a stage of reasonable maturity and respectability.”²¹

The extent to which NASA had served as the chief patron of cosmic biological evolution is evident in its sponsorship of many of the major conferences on extraterrestrial life, although the Academies of Science of the United States and the USSR were also prominent supporters. It was NASA that adopted exobiology as one of the prime goals of space science, and it was from NASA that funding would come, despite an early but abortive interest at the National Science Foundation.²² Pushed by prominent biologists such as Joshua Lederberg, beginning already in the late 1950s soon after its origin, NASA poured a small but steady stream of money into exobiology and the life sciences in general. By 1976, \$100 million had been spent on the Viking biology experiments designed to search for life on Mars from two spacecraft landers. Even as exobiology saw a slump in the 1980s in the aftermath of the Viking failure to detect life on Mars unambiguously, NASA kept exobiology alive with a grant program at the level of \$10 million per year, the largest exobiology laboratory in the world at its Ames Research Center, and evocative images of cosmic evolution (Figure 1). Cosmic evolution’s potential by the early 1960s to become a research program was converted to reality by NASA funding.

This is true not only of NASA’s exobiology laboratory and grants program, but also of its SETI program. Born at Ames in the late 1960s, quite



Figure 1. Cosmic evolution is depicted in this image from the exobiology program at NASA Ames Research Center (ARC), 1986. Upper left: the formation of stars, the production of heavy elements, and the formation of planetary systems, including our own. At left prebiotic molecules, RNA, and DNA are formed within the first billion years on primitive Earth. At center: the origin and evolution of life leads to increasing complexity, culminating with intelligence, technology, and astronomers. Upper right: contemplating the universe. The image was created by David DesMarais, Thomas Scattergood, and Linda Jahnke at ARC in 1986 and reissued in 1997.

separate from the exobiology program, NASA SETI expended some \$55 million prior to its termination by Congress in 1993. It was the NASA SETI program that was the flag bearer of cosmic evolution. As it attempted to determine how many planets might have evolved intelligent life, all of the parameters of cosmic evolution, as encapsulated in the Drake Equation, came into play.

With the demise of a publicly funded NASA SETI program in 1993, the research program of cosmic evolution did not end. The remnants of the NASA SETI program were continued with private funding, and similar, if smaller, SETI endeavors are still carried out around the world. Within NASA, a program of cosmic evolution research continued, with its images subtly changed. In 1995, NASA announced its Origins program, which two years later it described in its Origins Roadmap as “following the 15 billion year long chain of events from the birth of the universe at the Big Bang, through the formation of chemical elements, galaxies, stars, and planets, through the mixing of chemicals and energy that cradles life on Earth, to the earliest self-replicating organisms—and the profusion of life.” Any depiction of “intelligence” is conspicuously absent from the new imagery (Figure 2), for due to congressional action, programmatically it could no longer be supported with public funding. With this proclamation of a new Origins program, cosmic

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Figure 2. Cosmic evolution, as it appeared in the Roadmap for NASA's Office of Space Science Origins Theme, 1997 and 2000.

evolution became the organizing principle for most of NASA's space science effort. In a broad sense, most of NASA's space science program can be seen as filling in the gaps in the story of cosmic evolution.

In 1996 the "Astrobiology" program was added to NASA's lexicon. The NASA Astrobiology Institute, centered at NASA's Ames Research Center, funds numerous centers nationwide for research in astrobiology at the level of several tens of millions of dollars. Its paradigm is also cosmic evolution, even if it also tends to avoid mention of extraterrestrial intelligence due to congressional disapproval stemming from cancellation of the NASA SETI program in 1993. No such restriction is evident at the SETI Institute in Mountain View, California, headed by Frank Drake. The Institute has under its purview tens of millions of dollars in grants, all geared to answering various parameters of the Drake Equation, the embodiment of cosmic evolution, including the search for intelligence.

As we enter the 21st century, there is no doubt about the existence of a robust cosmic evolution research program. NASA is its primary patron and even many scientists without government funding now see their work in the context of this research program. Other agencies, including the European Space Agency, are also funding research essentially in line with the Origins and Astrobiology programs, not to mention their spacecraft, which help to fill in the gaps in the grand narrative of cosmic evolution. Within the last 40 years, all the elements of a new discipline gradually came into place: the cognitive elements, the funding resources, and the community and communications structures common to new disciplines. As we enter the 21st century, cosmic evolution is a thriving enterprise, providing the framework for an expansive research program and drawing in young talent sure to perpetuate a new field of science that a half century ago was nonexistent.

Cosmic Evolution and Culture

Since Darwin propounded his theory of evolution by natural selection, evolution has been much more than a science. It has been a worldview that has affected culture in numerous ways, and different cultures in diverse ways.²³ As we have noted, in her history of the modern evolutionary synthesis in biology, historian Betty Smocovitis found that by the late 1950s and early 1960s the wider culture was "permeated with evolutionary science" and "resonated with evolutionary themes."²⁴ The leaders of that evolutionary synthesis, including Julian Huxley, Theodosius Dobzhansky, Ernst Mayr, and George Gaylord Simpson, espoused an "evolutionary humanism," a secular progressive vision of the world that, for Huxley at least, was "the central feature of his worldview

and of his scientific endeavors.” In books and articles, each of these scientists addressed the future of mankind in evolutionary terms. Huxley (grandson of Darwin’s chief defender T. H. Huxley) “offered an inquiry . . . into an ethical system, an ethos, grounded in evolution, now a legitimate science, with its fundamental principle of natural selection, verifiable and testable through observation and experiment.” Cosmic evolution was part of this worldview, even if Mayr and Simpson would later express serious doubts about the chances for success of exobiology and SETI programs.²⁵

As Palmeri also points out in Chapter 15 of this volume, in the 1950s and 1960s Harlow Shapley was a prime example of a cosmic evolution evangelist from the astronomical side, being among the first to popularize the cosmic evolutionary perspective with “missionary zeal.” In Shapley’s view, this perspective inspired a religious attitude, should be incorporated into current religious traditions, and went beyond those traditions in questioning the need for the supernatural. He even spoke of a “stellar theology,” a view that had broader implication for ethics. Cosmic evolution has also been used to bolster the idea of biological evolution, though apparently with little impact to this day among skeptical Americans. Shapley’s books *Of Stars and Men: The Human Response to an Expanding Universe* (1958), *The View from a Distant Star* (1963), and *Beyond the Observatory* (1967) spread these ideas worldwide.

During the second half of the 20th century, then, the evolutionary view of the universe was not only fully in place both from the point of view of at least some astronomers and biologists, but was also spreading to the broader culture. Instead of the small and relatively static universe accepted at the turn of the 20th century, humanity was now asked to absorb the idea of an expanding (now known to be accelerating) universe 13.7 billion light-years in extent, full of billions of evolving galaxies floating in an Einsteinian space time with no center. The Big Bang theory, though still in competition in the 1950s with Fred Hoyle’s Steady State theory that denied an overarching linear cosmic evolution, would receive increasing confirmation through the detection of the cosmic microwave background in 1965, and its study at ever-finer resolution through the COBE and WMAP satellites. The Hubble Space Telescope and other spacecraft brought the impact of this worldview directly to the people, through spectacular imagery of objects in the evolutionary narrative, and through more global images such as the Hubble Deep Field. The biological universe full of life was conjectured, but not proven, though SETI and astrobiology programs received much popular attention, particularly in the case of the supposed fossil life found in the Mars rock (evidence hotly contested, in part because of the high stakes for broader worldviews).²⁶

In seeking the impact of the new universe on culture in the modern era, we need to remember that “culture” is not monolithic and that “impact” is a notoriously vague term. Thus it is no surprise that the new universe and its master narrative of cosmic evolution evoked different meanings for different groups. Cosmic consciousness in the form of a biological universe was expressed in many forms in popular culture, some of them unpalatable to most scientists: belief in UFOs and extraterrestrial abduction, space-oriented religious cults, and ever more elaborate alien scenarios in science fiction. Indeed, all three of these developments may be seen as ways that popular culture attempts to work out the worldview implied by the new universe. The UFO debate and alien science fiction both had their predecessors in the late 19th century, but only in the second half of the 20th century did they come into their own as major elements of popular culture. During this time, evolutionary themes became common in science fiction, notably in Arthur C. Clarke’s work such as *Childhood’s End*. Some of the most popular films of all times featured aliens, among them *Star Wars*, *Close Encounters of the Third Kind*, *ET: The Extraterrestrial*, *War of the Worlds*, and *Men in Black*. Obviously, and understandably, popular culture became preoccupied with whether the biological universe is hostile or friendly.²⁷

Although human reactions to the new universe and cosmic evolution have not been monolithic, certain underlying themes are pervasive. The increased awareness of the new universe and the possibility of a biological universe largely dashed any remaining hopes for an anthropocentric universe with all that implies for religion and philosophy.²⁸ Even though the idea that the universe was made for humans survives in the form of the elegantly misnamed “anthropic principle,” in fact that principle is (to use L. J. Henderson’s term from 1913 mentioned earlier), a “biocentric” principle of the fine-tuning of universal laws that points to the possible abundance of life in the universe in many forms, rather in human form only.²⁹ And if life is common throughout the universe, then our religions, philosophies, and other human endeavors are too parochial and will need to be significantly altered, expanded, or discarded. As physicist Paul Davies has said, “if it turns out to be the case that the universe is biofriendly . . . then . . . the scientific, theological and philosophical implications will be extremely significant.”

The religious and philosophical implications of astronomical discoveries have been discussed especially since the time of the Copernican revolution, which made Earth a planet and the planets potential Earths.³⁰ A few far-sighted thinkers reflected these implications in the early 20th century. Much to the chagrin of the Catholic Church, the French Jesuit priest, philosopher,

and paleontologist, Pierre Teilhard de Chardin, famously made the evolution of the cosmos the central theme of his posthumous book *The Phenomenon of Man* (1955). Here he embraced cosmic evolution, and argued for a teleological evolution in which man would end in a collective consciousness called the “noosphere,” which would ultimately lead to the Omega Point, the maximum level of consciousness, which he also identified with God.³¹ Though the idea was not accepted within the Catholic church, a few have followed in Teilhard’s footsteps, including the Catholic priest Thomas Berry and physicist Brian Swimme, whose book *The Universe Story*, emphasizes the religious significance of cosmic evolution.³²

The new universe of the late 20th century has spawned renewed analysis of the relation of humans to the cosmos, both inside and outside established religions. Biologist Ursula Goodenough argues in *The Sacred Depths of Nature* that cosmic evolution is a shared worldview capable of evoking an abiding religious response. “Any global tradition,” she writes, “needs to begin with a shared worldview—a culture-independent, globally accepted consensus as to how things are.” She finds this consensus in “our scientific account of Nature, an account that can be called The Epic of Evolution. The Big Bang, the formation of stars and planets, the origin and evolution of life on this planet, the advent of human consciousness and the resultant evolution of cultures—this is the story, the one story, that has the potential to unite us, because it happens to be true.”³³ She calls her elaboration of the religious implications “religious naturalism.”

Similarly, but with the Christian tradition, the British biochemist and Anglican priest, Sir Arthur Peacocke, has called cosmic evolution “Genesis for the third millennium.” He believes that “any theology—any attempt to relate God to all-that-is—will be moribund and doomed if it does not incorporate this perspective [of cosmic evolution] into its very bloodstream.”³⁴ Michael Dowd and Connie Barlow, who consider themselves, “evangelists of cosmic evolution,” have proposed “evolutionary Christianity”—very different from Huxley’s evolutionary humanism, but both with evolution as a central concept. Evolutionary Christianity embraces cosmic evolution, variously termed “the Great Story” and the “epic of evolution,” much more than did Huxley’s original evolutionary humanism, undoubtedly because cosmic evolution has been so much more developed over the last 50 years, complete with evocative images from the Hubble Space Telescope.³⁵

While Freeman Dyson among others have argued that the age-old mystery of God will be little changed by human attempts to read his mind, others argue that the new universe not only could, but should, lead to a new

“cosmotheology” or a new “cosmophilosophy.” Among the elements such a cosmotheology must take into account are 1) that humanity is in no way physically central to the universe, but located on a small planet circling a star on the outskirts of the Milky Way galaxy; 2) that humanity is probably not central biologically, even if our morphology may be unique; 3) that humanity is likely somewhere near the bottom, or at best midway, in the great chain of being—a likelihood that follows from the age of the universe and the youth of our species; 4) that we must be open to radically new conceptions of God grounded in cosmic evolution, including the idea of a “natural” rather than a “supernatural” God; and 5) that it must have a moral dimension, a reverence and respect for life that includes all species in the universe.³⁶

Each of these elements of cosmotheology provides vast scope for elaboration. Perhaps the most radical consequences stem from the fourth principle that states that we must be open to new conceptions of God, stemming from our advancing knowledge of cosmic evolution and the universe in general. As the God of the ancient Near East stemmed from ideas of supernaturalism, our concept of a modern God could stem from modern ideas divorced from supernaturalism. The billions of people attached to current theologies may consider this no theology at all, for a transcendent God above and beyond nature is the very definition of their theology. The supernatural God “meme,” which we should remember is an historical idea the same as any other, has been very efficient in spreading over the last few thousand years, picking up new memes such as those accepted by Christianity and other religions. Nonetheless, the idea of a “natural” God in the sense of a superior intelligence is appealing to some. A natural God need not intervene in human history, nor be the cause for religious wars such as witnessed through human history. It remains an open question whether a natural God fulfills the apparent need that many have for “the Other”; such a “God” is different enough from tradition concepts that some may wish to call it a cosmophilosophy rather than a cosmotheology.³⁷ In any case some will see it as an important part of religious naturalism.

Over the next centuries or millennia, religions will likely adjust to these cosmotheological principles. The adjustment will be most wrenching for those monotheistic religions that see man in the image of God (Judaism, Christianity, and Islam), a one-to-one relationship with a single godhead. It will be less wrenching for Oriental religions that teach salvation through individual enlightenment (Buddhism and Hinduism) rather than through a Savior, or that are this-worldly (Confucianism) rather than other-worldly. The adjustment will be not be to the physical world, as in Copernicanism,

nor to the biological world, as in Darwinism, where man descended from the apes but still remained at the top of the terrestrial world. Rather the adjustment will be to the biological, or even postbiological, universe, in which intelligences are likely to be superior to us.

Even the possibility of life beyond Earth raises such theological questions, but particularly intriguing are impact scenarios in the event of the actual discovery of such life. The impact would undoubtedly very much depend on how the discovery was made and the nature of the discovery. Finding microbial life and even complex but nonsentient life might be of more interest to science than to philosophy or theology as scientists probed the nature of the newfound life and determined whether it was based on the same DNA structure and biochemistry as life on Earth. The discovery of intelligent life, on the other hand, would be of immediate interest not only to science, but to such age-old philosophical problems as the nature of objective knowledge (would we perceive the universe in the same way as extraterrestrials?) and theology, typically meaning the relationship between humans and God, but now recast as the relationship between all intelligent beings in the universe and God. In general, the urgency of the societal implications of extraterrestrial intelligence would depend on whether physical contact was made (considered unlikely to the extent that evidence for UFOs is weak), or if contact was made via a remote radio signal through a SETI program. If the latter, a great deal would depend on the message received, if indeed it were decipherable.

While all of these scenarios are interesting to contemplate, most compelling, and most discussed, is the problem of how the discovery of clear evidence of a signal from extraterrestrial intelligence would affect theology on Earth, even if no message were deciphered. This is still a complex question because there are many terrestrial theologies and they would undoubtedly be affected in different ways. And there would be much discussion, and perhaps no consensus, even within a particular theology. We know this will be the case because the discussion has already been underway for over 500 years. As Michael J. Crowe—one of the premier historians of the extraterrestrial life debate—has emphasized, extraterrestrials have already influenced life on Earth and the history of ideas in many areas in the sense that the possibility of their existence and the implications of their discovery have been the subject of discussion for centuries.³⁸

Real SETI programs in the 20th century, however, made the problem more real even if the same concerns were raised again and again.³⁹ Ernan McMullin (a priest and philosopher at the University of Notre Dame) and George Coyne (the Jesuit director of the Vatican Observatory) are among

those who have recently provided reflections from within the Catholic tradition. McMullin related the problem to that faced by 16th century Europeans discovering the peoples of Mesoamerica. Fully aware of Thomas Paine's objections to Christianity in the late 18th century, McMullin noted that "the proven reality of ETI [Extraterrestrial Intelligence] might even more effectively encourage a broadening among the theologians and religious believers generally of the realization that the Creator of a galactic universe may well choose to relate to creatures made in the Creator's own image in ways and on grounds as diverse as those creatures themselves." The problems of such a broadening of Christian doctrine related for McMullin to three issues: original sin, soul and body, and incarnation. He speculated that an omnipotent creator might want "to try more than once the fateful experiment of allowing freedom to a creature," such as the Eve/apple event in the Garden of Eden. He pointed to the possibility that aliens might or might not have souls; if they did "God also might elect to become incarnate in their nature or to interact in some other way with them" depending on their response to an Eden-like challenge. Regarding incarnation, which he calls "the defining doctrine of the Christian tradition," McMullin suggests that conflicting theological interpretations of that doctrine would influence anyone faced with the ETI situation. Thus the discovery of ETI would result in a range of answers from Christian theologians with regard to whether Christ would become incarnate on another world ranging from "certainly yes" to "certainly no." McMullin's own answer is "maybe."⁴⁰

George Coyne, at the time Director of the Vatican Observatory, posed similar reservations about a definitive answer. He concluded that with the discovery of ETI "theologians must accept a serious responsibility to rethink some fundamental realities within the context of religious belief."⁴¹ Among those realities are the nature of a human being, and whether Jesus Christ could exist on more than one planet a one time. While theologians are limited in their ability to answer such questions, varying interpretations of Christian doctrines suggests that were a discovery of ETI actually made, a way would be found for Christian doctrine to absorb it, though perhaps not easily. The alternative would be extinction, and Christianity has shown its ability to adapt to scientific discovery, if very slowly at times.

The extraterrestrial life debate has also stimulated Jewish thought about the implications of ETI. Rabbi Norman Lamm, for example, noted, "this challenge must be met forthrightly and honestly" and called those who shrink from pursuing it "parochial and provincial." Citing astronomers who emphasize our peripheral place in the new universe, Rabbi Lamm noted that "[n]ever

before have so many been so enthusiastic about being so trivial.” Cautioning that extraterrestrial life is far from proven, Lamm explored “a Jewish exotheology,” and concluded that “[a] God who can exercise providence over one billion earthmen can do so for then billion times that number of creatures throughout the universe.”⁴²

The case where an extraterrestrial message is decoded is even more startling. Astronomer Jill Tarter, a pioneer in the field of SETI, believes an extraterrestrial message, unambiguously decoded, might be “a missionary campaign without precedent in terrestrial history,” leading to the replacement of our diverse collection of terrestrial religions by a “universal religion.” Alternatively, a message that indicates long-lived extraterrestrials with no need for God or religion might undermine our religious worldview completely.⁴³

If there was any consensus, it was that terrestrial religions would adjust to extraterrestrials—an opinion echoed in late 20th century studies of religious attitudes toward the problem.⁴⁴ As McMullin and others have pointed out, various extraterrestrial theological scenarios have also been worked out in detail in science fiction, including C. S. Lewis’s *Perelandra* and Walter Miller’s *A Canticle for Leibowitz*. More recently, Maria Dorrit Russell has taken up these questions in her novels, *The Sparrow* and *Children of God*. These fictional scenarios nevertheless represent deep thought about a problem that has now been with us for 500 years in hypothetical form, and that will be given greater urgency as soon as a discovery is made.

The impact of the new cosmos and its master narrative of cosmic evolution need not be couched solely in terms of theology. Mark Lupisella and John Logsdon have proposed a “cosmocentric ethic,” which they characterize as one which “(1) places the universe at the center, or establishes the universe as the priority in a value system, (2) appeals to something characteristic of the universe (physical and/or metaphysical) which might then (3) provide a justification of value, presumably intrinsic value, and (4) allow for reasonably objective measurement of value.”⁴⁵ A cosmocentric ethic would have some of the same concerns as cosmotheology, devoid of the theological implications. For example, a cosmocentric ethic would dictate how we treat extraterrestrial life-forms, whether primitive or intelligent, taking into account not only our own homocentric interests, but also the interests of the other life-forms. The prospects of terraforming entire planets also raise the question of whether questions of terrestrial environmental ethics should be extended to the cosmic stage. In the context of spaceflight, human interaction in general—whether among ourselves or with other intelligence—would seem to demand a reorientation toward a cosmic rather than a geocentric perspective.

Quite aside from theological and philosophical implications, cosmic evolution provides humanity a cosmic context in time, allowing us to place humanity in the 13.7 billion-year history of the universe. Although it is difficult to grasp that span of time, attempts have been made for several decades using the “cosmic calendar,” which conflates the history of the universe into a single year, showing humans arising in the last 1.5 hours of the last day of cosmic history, with the European Age of Discovery taking place one second ago.⁴⁶ More substantively, a small but increasing discipline known as “big history” seeks to incorporate human history into cosmic history in a more systematic way.⁴⁷ As seen in Chapter 13 of this volume, big history links our understanding of human history with our understanding of other historical sciences, such as cosmology, geology, and biology. It allows us to appreciate the emergent properties of culture in the same way as the emergent properties along the earlier path of cosmic evolution. And it highlights our unique collective learning ability and capacity for symbolic thought that results in our need to find meaning. In short, it reintegrates humans with the long history of the cosmos whence they sprang.

Finally, cosmic evolution integrates humans into the cosmos quite literally by teaching us that we are all “star stuff.” Once again, Harlow Shapley was an early proponent of this perspective. “Mankind is made of star stuff,” he wrote already in 1963, “ruled by universal laws. The thread of cosmic evolution runs through this history, as through all phases of the universe—the microcosmos of atomic structures, molecular forms, and microscopic organisms, and the macrocosmos of higher organisms, planets, stars, and galaxies. Evolution is still proceeding in galaxies and man—to what end, we can only vaguely surmise.”⁴⁸ The colorful terminology of star stuff and “starfolk” was picked up by Carl Sagan among others; its integration of humans into the cosmos encourages us to be “at home in the universe” in the felicitous phrase used by several distinguished scientists in the late 20th century.⁴⁹ We now know that the atoms in our bodies were forged in nuclear reactions in stellar furnaces, spewed into the universe in supernovae explosions, and incorporated into our bodies through the long process of the evolution of life over the last 3.8 billion years on Earth. We recognize that after death, our bodily atoms will be dispersed once again through the universe, recycled to once again become star stuff in a cycle of events that will end only with the death of the universe itself. We are part and parcel of the universe, and at the hour of our death when we return to the universe, the old phrase from the *Book of Common Prayer* based on Genesis and often used in burial ceremonies—“earth to earth, ashes to ashes, dust to dust”—need only be slightly altered to

“earth to earth, ashes to ashes, stardust to stardust” to be literally true. Cosmic evolution provides us with a master narrative in which our own birth, life, and death are integral parts of the universe, without recourse to the supernatural. In the end, that may be the ultimate message of the new universe and cosmic evolution.⁵⁰

While only a small portion of humanity yet realizes the implications of the new universe and cosmic evolution, the incorporation of these ideas into educational curricula and the general reawakening to our place in the universe ensure these ideas are an increasingly important role in culture. Such educational curricula have emerged from the astrobiology and SETI programs, and are reaching an increasing number of students. The SETI Institute’s *Life in the Universe* curriculum “Voyages Through Time” provides standards-based materials for a one-year high school integrated science course using cosmic evolution as its unifying theme. Its six modules include Cosmic Evolution, Planetary Evolution, Origin of Life, Evolution of Life, Hominid Evolution, and Evolution of Technology. The Wright Center for Science Education at Tufts University is also a valuable educational resource directly centered on “Cosmic Evolution: From Big Bang to Humankind,” not surprising since the Center’s director is Eric Chaisson.⁵¹

Following in the tradition of Shapley’s *Of Stars and Men* (1958), a variety of popular books are also bringing cosmic evolution to a broader audience including Neil DeGrasse Tyson’s *Origins: Fourteen Billion Years of Cosmic Evolution* (also a Nova special on PBS); *The Universe Story: From the Primordial Flaring Forth to the Ecozoic Era—A Celebration of the Unfolding of the Cosmos* by physicist Brian Swimme and theologian Thomas Berry; *Children of the Stars: Our Origin, Evolution and Destiny* by astronomer Daniel Altschuler; and *Atoms of Science: An Exploration of Cosmic Evolution* by astrophysicist Hubert Reeves. In short, an increasing number of people around the world are seeing their place for the first time within this naturalistic worldview. This recognition represents for humanity a return to the cosmos, a more sophisticated integration of culture and cosmos that humans possessed when cultures began, ranging from Stonehenge and the ancient civilizations such as Sumer and Egypt to Native Americans and the Australian aborigines.⁵²

Cosmic Evolution and Human Destiny: Three Scenarios

In addition to the impact of the new universe on culture, cosmic evolution also provides a window on long-term human destiny. Although historians are understandably loathe to use the word “destiny,” associating it with the misguided “Manifest Destiny” doctrine in which American colonists viewed it as

their inherent right to expand westward and seize territory from the Native Americans, the word can and must be dissociated from that historical event. In fact, the concept of “destiny” has often been used in the context of theological discussion. A little over a month after the outbreak of World War II in 1939, theologian Reinhold Niebuhr began his Gifford Lectures on “Human Destiny,” published in 1941 under the title *The Nature and Destiny of Man*, in which he concluded that human destiny must lie outside of history, outside of nature, in the supernatural realm espoused by Christianity. In 1947, just after the War’s end, the French biophysicist and philosopher Pierre Lecomte du Noüy published his volume *Human Destiny*, which espoused confidence in the broad scope of evolution in the universe, but ultimately found human destiny in God. And as we have seen, human destiny was explicit in Teilhard de Chardin’s works, written in the first half of the 20th century.

In the realm of the natural world, in the broadest sense we have only a limited number of destinies whether we like it or not. Cosmic evolution provides at least three vastly different scenarios of what the long-term human future may be. The ultimate product of cosmic evolution may be only planets, stars, and galaxies—a “physical universe” in which life is extremely rare. This has, in fact, been our chief worldview for the last several millennia, the plurality of world tradition notwithstanding. Almost all of the history of astronomy, from Stonehenge through much of the 20th century, encompasses the people, the concepts, and the techniques that gave rise to our knowledge of the physical universe. Babylonian and Greek models of planetary motion; medieval commentaries on Aristotle and Plato; the astonishing advances of Galileo, Kepler, Newton, and their comrades in the Scientific Revolution; the details of planetary, stellar and galactic evolution—all these and more address the physical universe. The physical universe is truly amazing in its own right, boasting a whole bestiary of remarkable objects.

For millennia, our perceptions of the destiny of human life on Earth were tied to the physical universe as represented by the geocentric system associated with Aristotle, with Earth at the center and the heavens above. This cosmological worldview provided the very reference frame for daily life, religious and intellectual. Writers from Claudius Ptolemy to Dante Alighieri touted it as the true system of the world in which humans sought meaning. The heliocentric system of Copernicus changed all that, making Earth a planet and the planets potential Earths. Societal uproar followed this daring new cosmological worldview. Since then the history of modern astronomy has been one of the increasing decentralization of humanity. In the 1920s, Harlow Shapley showed our solar system at the periphery of our Milky Way

galaxy rather than its center, and since then billions of galaxies have been discovered beyond our own.⁵³

In the physical universe scenario, all is not lost with respect to the status of humanity. In a universe in which life on Earth is unique or rarely duplicated, humans may still have an important role. Indeed, in such a universe, stewardship of our pale blue dot takes on special significance for life in the universe depends on our actions over long periods of time bounded only by physical reality. In two billion years the Sun will have increased in brightness enough to induce a runaway greenhouse effect on our home planet. Long before that we will likely have escaped to another star, offering our species longevity. The process will repeat until star formation in galaxies halts in 100 trillion years.⁵⁴ Assuming we don't remain Earthbound, the destiny of life in the physical universe is for humans—sooner or later—to populate the universe. Many options exist for humans in a universe devoid of life and many scenarios in science fiction address this possibility. Isaac Asimov has played out one scenario in his Foundation series, and the philosopher John Leslie has addressed some of the philosophical implications.⁵⁵

The second possible outcome of cosmic evolution reveals a quite different destiny. The biological universe—the universe in which cosmic evolution commonly ends in life, mind, and intelligence—means that we will almost certainly interact with extraterrestrials. Ideas about a possible biological universe date back to ancient Greece in a history that is now well known.⁵⁶ It is the universe that astrobiology and SETI program are attempting to prove. There is again no lack of ideas about human-extraterrestrial interaction in such a universe. Science fiction is filled with possibilities, from the horrors of a war of the worlds to warm and fuzzy ETs. Arthur C. Clarke—author of *Childhood's End*, *Rendezvous with Rama*, and *2001: A Space Odyssey* and its sequels, among much other “alien literature”—is the prophet of this world-view replete with extraterrestrials. In such a universe, humanity may join what has been called a “galactic club” whose goal is to enhance knowledge.⁵⁷

Taking a long-term view not often discussed, cosmic evolution may have already resulted in a third scenario. Cultural evolution in a biological universe may have already produced, or replaced, biologicals with artificial intelligence, constituting what I have called a “postbiological universe.”⁵⁸ This idea requires us to take cultural evolution just as seriously as astronomical and biological evolution. It requires us to contemplate cultural evolution on cosmic “Stapledonian” time scales as did Olaf Stapledon in his novels *Last and First Men* (1930) and *Star Maker* (1937). While astronomers are accustomed to thinking in these terms for physical processes, they are not accustomed to

thinking on cosmic time scales for biology and culture. But cultural evolution now completely dominates biological evolution on Earth. Given the age of the universe, and if intelligence is common, it may have evolved far beyond us. If intelligence is highly valued for its evolutionary advantage, extraterrestrials would long ago have sought the best way to improve their intelligence, and it is likely to have involved artificial intelligence, yielding the postbiological universe. Nor does *L*, the lifetime of a technological civilization, need to be millions of years for such a scenario. It is possible that such a universe would exist if *L* exceeds a few hundred or a few thousand years where *L* is defined as the lifetime of a technological civilization that has entered the electronic computer age (which on Earth approximately coincides with the usual definition of *L* as a radio communicative civilization.) Indeed, some predict Earth will be postbiological in a few generations.⁵⁹

Such a postbiological universe would have sweeping implications for SETI strategies, for our worldview, and for the destiny of life on Earth if it has already happened throughout the universe. We may see our own future in the evolution of extraterrestrial civilizations, perhaps another motivation for searching. How such postbiologicals—whether terrestrial or extraterrestrial—would use their knowledge and intelligence is a valuable question that, at present, is unanswerable. Whether one relishes or opposes the idea of a universe dominated by machines, the transition to such a universe presents many moral dilemmas and raises with renewed urgency the ancient philosophical question of destiny and free will.

In short, both in our relationship with extraterrestrials and with God—however conceived—human destiny would be quite different in a universe full of biologicals or postbiologicals than if we were alone. If extraterrestrial intelligence is abundant, it will be our destiny to interact with that intelligence—whether for good or ill—for life identifies with life. It is here that the fifth Cosmotheological Principle, or the cosmocentric ethic, comes into play. The moral dimension—a reverence and respect for extraterrestrial intelligence that may be morphologically very different from terrestrial life-forms—will surely challenge a species that has come to blows over superficial racial and national differences. If we are wise, humanity will realize that our species is one—a necessary realization before we have any hope of dealing with extraterrestrial beings in a morally responsible way.

Although the physical, biological, and postbiological universe may be facts that the universe imposes on us, humans will still have great scope for choice and free will within these broad scenarios. The founders of the modern evolutionary synthesis emphasized this point already at the middle

of the 20th century. George Gaylord Simpson for one, echoing Huxley's evolutionary humanism, wrote, "it is another unique quality of man that he, for the first time in the history of life, has increasing power to choose his course and to influence his own future evolution. It would be rash, indeed, to attempt to predict his choice. The possibility of choice can be shown to exist. This makes rational the hope that choice may sometime lead to what is good and right for man. Responsibility for defining and for seeking that end belongs to all of us."⁶⁰

Whether intelligence is rare or abundant, whether extraterrestrial life is of a lower order or a higher order than *Homo sapiens*, human destiny is intimately connected with cosmic evolution. Driven by the astronomical, biological, and cultural components of cosmic evolution, the universe may have generated any of the three outcomes described here: the physical universe, the biological universe, or the postbiological universe. Which of the three the universe has produced in reality we do not yet know—this is one of the many challenges of astrobiology with its goal of analyzing the future of life as well as its past and present. Ours may be a cosmos in which humanity is not central, yet where humans can be at home in the universe in which they play a role. Whatever its long-term destiny, it is surely the destiny of humanity in the near future to follow the trail of scientific evidence wherever it may lead even if it means abandoning old scientific, philosophical, and theological ideas. Humans have always known intuitively that culture and cosmos are intertwined. We are just now beginning to realize what this coevolution may mean.

Endnotes

1. Carl Sagan, *The Cosmic Connection: An Extraterrestrial Perspective* (Garden City, NY: Doubleday, 1973). After Sagan's death the book was reissued as *Carl Sagan's Cosmic Connection: An Extraterrestrial Perspective* (Cambridge and New York: Cambridge University Press, 2000), with new contributions by Freeman Dyson, Ann Druyan, and David Morrison.
2. Percival Lowell confined himself to planets in *The Evolution of Worlds* (New York: Macmillan Company, 1909) and George Ellery Hale dealt only with stars in *The Study of Stellar Evolution* (Chicago: University of Chicago Press, 1908). Among historians, stellar evolution has been treated in David DeVorkin's work on the development of the Hertzsprung-Russell diagram, but no history of ideas of cosmic evolution exists.

3. In making the distinctions between physical, biological, and cultural evolution, I do not mean to deny their physical basis, but rather to imply that the three possible endpoints of cosmic evolution are physical, biological, and cultural, a point elaborated in the last section of this paper. Biological and cultural evolution cannot occur without their physical basis. This vast sweep of evolution was enunciated already in 1957 by evolutionary biologist Julian Huxley, among others, notably in his *New Bottles for New Wine* (New York: Harper and Brothers, 1957).
4. On the natural selection of universes, see Lee Smolin, *The Life of the Cosmos* (New York and Oxford: Oxford University Press, 1997). Freeman Dyson, *Infinite in All Directions* (New York: Harper and Row, 1988), p. 51, proposes “cosmic ecology.” It is important to note that “evolution” has general and specific meanings. When scientists speak about “cosmic evolution” they usually have a general idea of “development” in mind. When Smolin speaks of the “natural selection” of universes that may compose the multiverse, he is applying the more specific idea of Darwinian evolution to astronomy. On the general idea of evolution see Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley and Los Angeles: University of California Press, 1983; revised edition, 1989).
5. Michael J. Crowe, *The Extraterrestrial Life Debate, 1750–1900* (Cambridge: Cambridge University Press, 1986), pp. 224–225, 274–277, 464–465. Simon Schaffer has shown the place of the nebular hypothesis in a general “science of progress” in early Victorian Britain, “The Nebular Hypothesis and the Science of Progress,” in *History, Humanity and Evolution: Essays for John C. Greene*, J. R. Moore, ed. (Cambridge: Cambridge University Press, 1989), pp. 131–164. On the role of Spencer and Fiske in 19th century origin of life debates, see James Strick, *Sparks of Life: Darwinism and the Victorian Debates over Spontaneous Generation* (Cambridge, MA: Harvard University Press, 2000), pp. 94–95 and passim.
6. See Proctor’s *Other Worlds than Ours* (London, 1870), *Our Place among Infinities* and *Science Byways*—the latter published in 1875, and the 1872 edition of Flammarion’s *La pluralité des mondes*. Flammarion’s *La pluralité* reached 33 editions by 1880 and was reprinted until 1921, while Proctor’s *Other Worlds than Ours* reached 29 printings by 1909, making him the most widely read astronomy writer in the English language. On Proctor and Flammarion see Crowe, *The Extraterrestrial Life Debate*, pp.

367–386. In his book *Victorian Popularizers of Science: Designing Nature for New Audiences* (Chicago: University of Chicago Press: 2007), historian Bernard Lightman makes the case that these and lesser known popularizers used the concept of cosmic evolution to narrate an evolutionary epic long before it was accepted by scientists or incorporated into any research program. An early case of 19th century astronomical evolution is the astronomer/popularizer Robert S. Ball, “The Relation of Darwinism to other Branches of Science,” *Longman’s Review* 2 (November 1883): 76–92.

7. On Lowell as Spencerian, and as influenced by Spencer’s American disciple John Fiske, see David Strauss, *Percival Lowell: The Culture and Science of a Boston Brahmin* (Cambridge, MA: Harvard University Press, 2001), pp. 97–165.
8. W. W. Campbell, “The Daily Influences of Astronomy,” *Science* 52 (10 December 1920): 543–552, 540. David DeVorkin had found archival evidence that Hale’s interest in cosmic evolution extended beyond the physical universe to the biology and culture; “Evolutionary Thinking in American Astronomy from Lane to Russell,” presented at a session on “Evolution and 20th Century Astronomy,” History of Science Society Meeting, Denver, Colorado, 8 November 2001.
9. Helge Kragh, *Cosmology and Controversy: The Historical Development of Two Theories of the Universe* (Princeton, NJ: Princeton University Press, 1996), p. 4. See also Stephen Toulmin and June Goodfield, *The Discovery of Time* (Chicago: University of Chicago Press, 1982).
10. The quotation is from A. R. Wallace, “Man’s Place in the Universe,” *The Independent* (New York) 55: 473–483: 474. This was expanded into a book *Man’s Place in the Universe* (London and New York: McClure, Phillips & Co., 1903), and Wallace’s thoughts on the improbabilities of humans on any other planet are found in the Appendix to its London, 1904 edition, pp. 326–336. On Wallace’s astronomy see Steven J. Dick, “The Universe and Alfred Russel Wallace,” in Charles H. Smith and George Beccaloni, eds., *Natural Selection and Beyond: The Intellectual Legacy of Alfred Russel Wallace* (Oxford: Oxford University Press, 2008), pp. 320–340; also Dick, *The Biological Universe* (reference 14 below), chapter 1. On Wallace himself see Michael Shermer, *In Darwin’s Shadow: The Life and Science*

of *Alfred Russel Wallace* (Oxford: Oxford University Press, 2002); for Wallace's "heresy" in breaking with Darwin on the matter of the evolution of the human brain, see pp. 157–162.

11. L. J. Henderson, *The Fitness of the Environment* (New York: MacMillan Company, 1913), reprinted with an Introduction by Harvard biologist George Wald (Gloucester, MA: Peter Smith, 1970), p. 312. The complexity of Henderson's ideas on the fitness of the environment and their connection to modern ideas on the subject are analyzed in detail in Iris Fry, "On the Biological Significance of the Properties of Matter: L. J. Henderson's Theory of the Fitness of the Environment," *J. History of Biology* 29 (1996): 155–196.
12. Helge Kragh, *Cosmology and Controversy* (1996), reference 9.
13. Vassiliki Betty Smocovitis, *Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology* (Princeton, NJ: Princeton University Press, 1996), p. 165.
14. Dick, *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge: Cambridge University Press, 1996), chapter 4.
15. Spencer Jones, *Life on Other Worlds* (New York: MacMillan, 1940), p. 57. On Oparin see Iris Fry, *The Emergence of Life on Earth: A Historical and Scientific Overview* (New Brunswick, NJ: Rutgers University Press, 2000), chapter 6, and Dick, *The Biological Universe*, chapter 7.
16. A. I. Oparin and V. G. Fesenkov, *Life in the Universe* (New York, 1961); George Wald, "The Origin of Life," *Scientific American* (August, 1954): 44.
17. For details of SETI history see Dick, *The Biological Universe*, chapter 8.
18. Joseph Shklovskii and Carl Sagan, *Intelligent Life in the Universe* (San Francisco: Holden-Day, 1966). In May 1964, the Armenian Academy of Sciences sponsored a meeting on extraterrestrial intelligence at Byurakan Astrophysical Observatory. The Proceedings are G. M. Tovmasyan, ed., *Extraterrestrial Civilizations* (1965; English translation, 1967). For a list of further Soviet meetings see Dick, *The Biological Universe*, pp. 484–485.

19. On Shapley's uses of cosmic evolution see JoAnn Palmeri, chapter 15 in this volume, and her dissertation, "An Astronomer Beyond the Observatory: Harlow Shapley as Prophet of Science," (University of Oklahoma, 2000).
20. While Sagan's views have reached a vast worldwide audience through the TV series *Cosmos*, Chaisson has been most persistent and explicit about cosmic evolution as a leading idea and about its impact on culture. In addition to *Cosmic Dawn*, see *The Life Era: Cosmic Selection and Conscious Evolution* (New York: W.W. Norton, 1987); *Cosmic Evolution: The Rise of Complexity in Nature* (Cambridge, MA: Harvard University Press, 2001); and *Epic of Evolution: Seven Ages of the Cosmos* (New York: Columbia University Press, 2006). In addition see his Web site at http://www.tufts.edu/as/wright_center/cosmic_evolution/docs/splash.html.
21. Otto Struve, "Life on Other Worlds," *Sky and Telescope* 14 (February 1955): 137–146; Joshua Lederberg, "Exobiology: Experimental Approaches to Life Beyond the Earth," in Lloyd V. Berkner and Hugh Odishaw, *Science in Space* (New York: McGraw Hill, 1961), pp. 407–425; John Billingham, *Life in the Universe* (Cambridge, MA: MIT Press, 1981), p. ix.
22. In 1960 the NSF's John Wilson looked forward to funding space biology. But NASA took an early dominant lead, which it has continued to hold. By 1963 NASA's life sciences expenditures (including exobiology) had already reached \$17.5 million. Toby Appel, *Shaping Biology: The National Science Foundation and American Biological Research, 1952–1975* (Baltimore: Johns Hopkins University Press, 2000), p. 132.
23. John C. Greene, *Science, Ideology and World View: Essays in the History of Evolutionary Ideas* (Berkeley: University of California Press, 1981) and Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley: University of California Press, revised edition, 1989).
24. Smocovitis, *Unifying Biology*, pp. 142–153: 148. Connie Barlow's book of readings, *Evolution Extended: Biological Debates on the Meaning of Life* (Cambridge, MA: MIT Press, 1995), clearly shows these wider evolutionary themes.

25. Smocovitis, *Unifying Biology*, pp. 139, 146–148. See Julian Huxley, *Evolutionary Humanism* (Buffalo, NY: Prometheus books, 1992; first edition 1964); Theodosius Dobzhansky, *Mankind Evolving: The Evolution of the Human Species* (New Haven and London: Yale University Press, 1969; first edition, 1962), especially chapter 12; George Gaylord Simpson, *The Meaning of Evolution: A Study of the History of Life and of its Significance for Man* (New Haven, CT: Yale University Press, 1949). On the connections of evolution and extraterrestrial life see Dick, *The Biological Universe*, pp. 389–398.
26. Kathy Sawyer, *The Rock from Mars: A Detective Story on Two Planets* (New York: Random House, 2006).
27. See Dick, *The Biological Universe*, chapter 5.
28. On the increasing decentralization of humans through history see Richard Berenzden, “Geocentric to Heliocentric to Galactocentric to Acentric: The Continuing Assault on the Egocentric,” in Arthur Beer and K. Aa. Strand, eds., *Copernicus: Yesterday and Today* (Oxford: Pergamon Press, 1975), pp. 65–83; also Peter van de Kamp, “The Galactocentric Revolution: A Reminiscent Narrative,” *Publications of the Astronomical Society of the Pacific* 77 (October 1965): 325–335. For an important history that expresses a contrary view on the place of the Earth and humans in the universe see Dennis Danielson, “The Great Copernican Cliché,” *American Journal of Physics* 69, no. 10 (October 2001): 1029–1035 and Danielson, “The Bones of Copernicus,” *American Scientist* 97, no. 1 (January–February 2009): 50–57.
29. On the anthropic principle and its philosophical implications see John Barrow and Frank Tipler, *The Anthropic Cosmological Principle* (New York: Oxford University Press, 1986), *Universe or Multiverse?* Bernard Carr, ed. (Cambridge: Cambridge University Press, 2007) and Steven J. Dick, “Cosmology and Biology,” *Proceedings of the 2008 Conference of the Society of Amateur Radio Astronomers* (American Radio Relay League; National Radio Astronomy Observatory, Green Bank, WV, 2008), pp. 1–16.
30. The intellectual transformation wrought by the Copernican theory has been discussed in Hans Blumenthal, *The Genesis of the Copernican World* (Cambridge, MA: MIT Press, 1987); Thomas Kuhn, *The Copernican*

Revolution: Planetary Astronomy in the Development of Western Thought (Cambridge, MA: Harvard University Press, 1992), and Steven J. Dick, *Plurality of Worlds*, chapter 4.

31. Teilhard de Chardin, *The Phenomenon of Man* (New York: Harper Collins, 2002), was first published in French in 1955, in English in 1959. The Harper edition also has an Introduction by Sir Julian Huxley. See also Teilhard's *The Future of Man* (New York: Doubleday, 2004), and on Teilhard himself Ursula King, *The Life and Vision of Teilhard de Chardin* (New York: Orbis Books, 1996).
32. Thomas Berry and Brian Swimme, *The Universe Story; From the Primordial Flaring Forth to the Ecozoic Era—A Celebration of the Unfolding of the Cosmos* (New York: Harper, 1994).
33. Ursula Goodenough, *The Sacred Depths of Nature* (Oxford: Oxford University Press, 1998).
34. Arthur Peacocke, "The Challenge and Stimulus of the Epic of Evolution to Theology," in Steven J. Dick, ed., *Many Worlds: The New Universe, Extraterrestrial Life and the Theological Implications* (Philadelphia: Templeton Foundation Press, 2000); Paul Davies, "Biological Determinism, Information Theory, and the Origin of Life," *ibid.*, pp. 15–28.
35. Rev. Michael Dowd, *Thank God for Evolution: How the Marriage of Science and Religion Will Transform Your Life and Our World* (New York: Viking, 2008), and "Evolutionary Christianity," DVD, described as "seeing the entire history of the Universe and emergent complexity of matter, life, consciousness, culture and technology is a God-glorifying, Christ-edifying way"; also Amy Hassinger, "Welcome to the Ecozoic Era," *UU[Unitarian Universalist] World* (Spring, 2006): 26–32. A major theme of Connie Barlow's edited volume *Evolution Extended: Biological Debates on the Meaning of Life* (Cambridge, MA: MIT Press, 1995) is the relationship between theology and evolution. See also their Web sites at <http://www.thegreatstory.org/CB-writings.html> and <http://www.thegreatstory.org/>.
36. Steven J. Dick, "Cosmotheology: Theological Implications of the New Universe," in Dick, *Many Worlds*, pp. 191–210; Steven J. Dick, "Kosmotheologie—Neu Betrachtet," in *Leben im All: Positionen aus*

Naturwissenschaft, Philosophie und Theologie, Tobias Daniel Wabbel, ed. (Dusseldorf, Germany: Patmos, 2005), pp. 156–172. The latter collection of essays shows interest in the subject is not limited to the English-speaking world.

37. The idea of a nontranscendent natural God has a long history, and has been raised most recently among scientists in Fred Hoyle, *The Intelligent Universe: A New View of Creation and Evolution* (New York: Holt, Rinehart and Winston, 1983); E. W. Harrison, “The Natural Selection of Universes Containing Intelligent Life,” *Quarterly Journal of the Royal Astronomical Society* 36, no. 3 (1995): 193; and James Gardner, *The Intelligent Universe: AI, ET and the Emerging Mind of the Cosmos* (Franklin Lakes, NJ: New Page Books, 2007), p. 159 and Gardner, *Biocosm: The New Scientific Theory of Evolution: Intelligent Life is the Architect of the Universe* (Makawao, Maui, HI: Inner Ocean Publishing, 2003).
38. For the historical discussion on theological implications of extraterrestrial life see Michael J. Crowe, “A History of the Extraterrestrial Life Debate,” *Zygon* 32 (June 1997): 147–162; Dick, *The Biological Universe* and R. O. Randolph, Margaret S. Race, and Chris P. McKay, “Reconsidering the Theological and Ethical Implications of Extraterrestrial Life,” *CTNS [Center for Theology and the Natural Sciences] Bulletin* 17, no. 3 (1997): 1–8.
39. Thomas F. O’Meara gives the best in-depth discussion of current thinking about extraterrestrials and Christianity in “Christian Theology and Extraterrestrial Intelligent Life” *Theological Studies* 60 (1999): 3–30. Another discussion is Ted Peters, “Exotheology: Speculations on Extraterrestrial Life,” chapter 6 in his *Science, Theology and Ethics* (Burlington, VT: Ashgate, 2003). The role of extraterrestrials in the Mormon church is detailed in Erich Robert Paul, *Science, Religion and Mormon Cosmology* (Urbana and Chicago: University of Illinois Press, 1992).
40. Ernan McMullin, “Life and Intelligence Far from Earth: Formulating Theological Issues,” in Steven J. Dick, ed., *Many Worlds*, pp. 151–176: 162, 169, 171.

41. George V. Coyne, "The Evolution of Intelligent Life on Earth and Possibly Elsewhere: Reflections from a Religious Tradition," in Dick, *Many Worlds*, pp. 177–190.
42. Norman Lamm, "The Religious Implications of Extraterrestrial Life," in *Challenge: Torah Views on Science and its Problems*, Aryeh Carmell and Cyril Domb, eds., (Jerusalem and New York: Feldheim, 1978), pp. 354–398.
43. Jill Tarter, "SETI and the Religions of the Universe," in Dick, *Many Worlds*, pp. 143–150.
44. See, for example, Michael Ashkenazi, "Not the Sons of Adam: Religious Response to ETI," *Space Policy* 8 (1992): 341–350. In interviews with 21 religious authorities from a variety of religions, the author found that none believed extraterrestrial intelligence created theological or religious problems, not even the 17 who believed such extraterrestrials existed. For the broader debate see Dick, *The Biological Universe*, pp. 514–526.
45. Mark Lupisella and John Logsdon, "Do We need a Cosmocentric Ethic?" (International Astronautical Congress paper IAA-97-IAA.9.2.09, 6-10 October 1997), p. 1.
46. Carl Sagan was among the first to use the Cosmic Calendar in his Pulitzer Prize-winning book, *The Dragons of Eden* (New York: Random House, 1977), chapter 1, and again in his Cosmos television series, first aired on PBS in 1980. It has been used as a teaching tool ever since; see, for example, <http://visav.phys.uvic.ca/~babul/AstroCourses/P303/BB-slide.htm>. Each month represents a little more than a billion years.
47. David Christian, *Maps of Time: An Introduction to 'Big History'* (Berkeley, CA: University of California Press, 2004) and Fred Spier, *The Structure of Big History: From the Big Bang Until Today* (Amsterdam: Amsterdam University Press, 1996).
48. Shapley, *The View from a Distant Star: Man's Future in the Universe* (New York: Basic Books, 1963), p. 5. See also Palmeri, chapter 15, this volume.

49. Stuart Kauffman, *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity* (Oxford: Oxford University Press, 1995); John Wheeler, *At Home in the Universe* (New York: Springer-Verlag, 1996).
50. The details of where the atoms of our bodies originate and how they are recycled are detailed in John Gribbin, *Stardust: Supernovae and Life—The Cosmic Connection* (New Haven: Yale University Press, 2000). The sentiment is found several times in the Bible: Ecclesiastes 3:20, “All go to one place; all are from the dust, and all turn to dust again”; Job 10:9, “Remember that you fashioned me like clay; and will you turn me to dust again?”; Job 34:15, “All flesh would perish together, and all mortals return to dust”; Genesis 3:19, “By the sweat of your face you shall eat bread until you return to the ground, for out of it you were taken; you are dust, and to dust you shall return.”
51. The curriculum, developed by the SETI Institute, the California Academy of Sciences, NASA Ames Research Center, and San Francisco State University, is available on CD-ROM. This and other educational curricula are described, and available, at <http://www.seti.org/epo>. The Wright Center program on cosmic evolution may be accessed at http://www.tufts.edu/as/wright_center/cosmic_evolution/docs/splash.html.
52. On this astronomical heritage, see E. C. Krupp, *Echoes of the Ancient Skies: The Astronomy of Lost Civilizations* (Cambridge, MA: Harper & Row, 1983).
53. See reference 28, including Danielson’s contrary view of the decentralization of humanity.
54. For an exciting explication of the physical evolution of the cosmos over the long term, see Fred Adams and Greg Laughlin, *The Five Ages of the Universe: Inside the Physics of Eternity* (New York: The Free Press, 1999). Adams and Laughlin distinguish five eras: primordial, stelliferous, degenerate, black hole, and the dark era.
55. John Leslie, *The End of the World: the Science and Ethics of Human Extinction* (London and New York: Routledge, 1996).

56. The history of the extraterrestrial life debate is treated in Steven J. Dick, *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate From Democritus to Kant* (Cambridge: Cambridge University Press, 1982); Steven J. Dick, *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge: Cambridge University Press, 1996) and its abridgement and update, *Life on Other Worlds* (Cambridge: Cambridge University Press, 1998); and Michael J. Crowe, *The Extraterrestrial Life Debate, 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell* (Cambridge: Cambridge University Press, 1986).
57. The history of ideas about a biological universe is in Dick, *The Biological Universe*. For an illustrated guide to the long-term possibilities of life see Peter Ward, *Future Evolution: An Illuminated History of Life to Come* (New York: Henry Holt and Co., 2001).
58. The arguments for such a universe are laid out in chapter 14 of this volume.
59. Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence* (Cambridge: Harvard University Press, 1988) and *Robot: Mere Machine to Transcendent Mind* (Oxford: Oxford University Press, 1999); Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (New York: Penguin Books, 1999) and *The Singularity is Near: When Humans Transcend Biology* (New York: Penguin Books, 2006).
60. Closing paragraph in George Gaylord Simpson, *The Meaning of Evolution* (New Haven: Yale University Press, 1949).