Chapter 14*

Bringing Culture to Cosmos
The Postbiological Universe

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The Biological Universe (Dick 1996) analyzed the history of the extraterrestrial life debate, documenting how scientists have assessed the chances of life beyond Earth during the 20th century. Here I propose another option—that we may in fact live in a postbiological universe, one that has evolved beyond flesh and blood intelligence to artificial intelligence (AI) that is a product of cultural rather than biological evolution. MacGowan and Ordway (1966), Davies (1995), and Shostak (1998), among others, have broached the subject, but the argument has not been given the attention it is due, nor has it been carried to its logical conclusion. This paper argues for the necessity of long-term thinking when contemplating the problem of intelligence in the universe. It provides arguments for a postbiological universe based on the likely age and lifetimes of technological civilizations and the overriding importance of cultural evolution as an element of cosmic evolution. And it describes the general nature of a postbiological universe and its implications for SETI.

The Necessity of Stapledonian Thinking

The possibility of a postbiological universe—one in which most intelligence has evolved beyond flesh and blood to AI—has not been considered in detail

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because humans are unaccustomed to thinking on cosmic time scales and following the logical consequences of cosmic time scales for biology and culture. The vast majority of humans think in terms of a human lifetime and the necessities for survival. Even historians span only the few thousand years of the rise and fall of civilizations, while anthropologists encompass the several million years of human origins, and geologists cover the 4.5-billion-year history of Earth. Only astronomers contemplate the 13.7-billion-year history of the cosmos, and the vast majority of them concentrate on the physical universe. Biologists—even paleobiologists and paleontologists—have never thought beyond the 3.8-billion-year history of life on Earth, and cultural evolution has rarely been considered beyond the evolution of culture on Earth. Yet, if biology and culture exist beyond Earth, the one thing we know for certain is that they will evolve.

Only science fiction writers have thought in these longer terms, beginning most notably with H. G. Wells's evocative picture of a terrestrial society of Moorlocks and Eloi in *The Time Machine* (1895). In the 20th century, the British philosopher Olaf Stapledon is the prime example of one who had a cosmic perspective on universal biological and cultural evolution, as played out in his novels *Last and First Men* (1930) and *Star Maker* (1937), and in some of his essay such as "Interplanetary Man?" (Stapledon 1948). We need, therefore, to think not only on astronomical time scales, but also on what I shall call Stapledonian time scales, by which I mean an astronomical time scale that takes into account the evolution of biology and culture. The foundation for the concept of a postbiological universe is the recognition of these time scales (Table 1), and the *necessity* for thinking in Stapledonian terms, no matter where it may lead. A primary methodological premise of this paper is that *long-term Stapledonian thinking is a necessity if we are to understand the nature of intelligence in the universe today*.

One small set of scientists that *has* thought on astronomical time scales about biology is SETI proponents. SETI enthusiasts, knowing the story of cosmic evolution, have often concluded that extraterrestrials must be older

Table 1. Time Scales in Human Thought.

Human	100
Historical	10,000 years
Anthropological	10 million years
Geological	5 billion years
Astronomical	14 billion years
Stapledonian	Biology and Culture on Astronomical Scale

and wiser than us (Shklovskii and Sagan 1966; Oliver 1971; Drake 1976). But they have not used Stapledonian thinking to carry this possibility to its logical conclusion—that biological and cultural evolution will make extraterrestrial intelligence far different from us. Why they have not done so is understandable from an operational viewpoint: SETI proponents wish to search for intelligence using current technology, so they prefer the option that extraterrestrials will have technology similar to ours. That *is* an option, but only one of many, and, possibly, not the most likely scenario.

By contrast, those who have no stake in standard SETI strategy have been more successful at adopting Stapledonian thinking. This is particularly true of proponents of the Fermi Paradox—formulated in 1950 even before radio searches were technologically feasible, elaborated in the 1970s and 1980s especially by Hart (1975) and Tipler (1985), and codified in a famous volume of essays (Hart and Zuckerman 1982). If there are so many civilizations in the galaxy, given the time scales involved, Hart, Tipler and their proponents ask, where are they? If extraterrestrials have acquired space travel, they should have colonized the galaxy in a few million years and should be here. They are not, therefore, they do not exist. Many solutions to the Fermi Paradox have been proposed over the last quarter century (Webb 2002). Suffice it to say that Tipler thought the rationale of the Fermi Paradox was strong enough that we should abandon all SETI programs. SETI proponents, among others, took strong exception to this claim. While Tipler's conclusion is not rigorous, it does embody the methodology of long-term thinking that needs to be applied to the problem of intelligence in the universe. The Fermi Paradox *does* need to be taken seriously.

Tipler's conclusion, however, is not the only possible outcome of long-term thinking about intelligence in the universe. In attempting to disprove extraterrestrials, Tipler argued that the galaxy would be colonized by self-reproducing automata—so-called von Neumann machines—with intelligence comparable to humans, but still under control of an intelligent flesh-and-blood species. Since he concluded extraterrestrials do not exist, for Tipler, machine intelligence also does not exist. But if there is a flaw in the logic of the Fermi Paradox and extraterrestrials *are* a natural outcome of cosmic evolution, then cultural evolution may have resulted in a postbiological universe in which machines are the predominant intelligence. This is more than mere conjecture; it is recognition of the fact that cultural evolution—the final frontier of the Drake Equation—needs to be taken into account no less than the astronomical and biological components of cosmic evolution (Chaisson 2001). Although the importance of cultural evolution was recognized very

Figure 1. The Drake Equation.

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Astronomical *Biological* *Cultural*

N = The number of technological civilizations in the galaxy.
R_* = The rate of formation of stars suitable for the development of intelligent life.
f_p = The fraction of those stars with planetary systems.
n_e = The number of planets in each planetary system with an environment suitable for life.
f_l = The fraction of suitable planets on which life actually appears.
f_i = The fraction of life-bearing planets on which intelligent life emerges.
f_c = The fraction of planets with intelligent life that develop technological civilizations.
L = The lifetime of a technological civilization.

early on in the modern SETI discussions (Ascher and Ascher 1962), including some of its pioneering documents (Stull 1977), it has been essentially ignored over the last four decades.

The missing element in all past SETI arguments has therefore been a failure to account fully for the effects of cultural evolution. To some extent, cultural evolution is embodied in the "L" parameter of the Drake Equation, the lifetime of a technological civilization (Figure 1). But, especially if one is interested in more than just "N" (the number of technological civilizations in the galaxy), many other aspects of cultural evolution are critical to understanding the nature of extraterrestrial intelligence. Moreover, the prevalence of artificial intelligence may be critical to L. Another primary methodological premise of this paper, then, is that *cultural evolution must be seen as an integral part of cosmic evolution and the Drake Equation*. Following this premise, one solution to the Fermi Paradox is that we live in a postbiological universe, in which the psychology of biological beings no longer rules. While SETI proponents might rejoice in yet another solution to the Fermi Paradox, the postbiological universe has other important implications for SETI that must be taken into account in SETI strategies. But before addressing these implications, we must examine the likelihood that we indeed inhabit a postbiological universe.

Arguments for a Postbiological Universe

In setting forth arguments for a postbiological universe, it is important to define the term more precisely. It cannot mean a universe totally devoid of biological intelligence since we are an obvious counterexample. Nor does it mean a universe devoid of lower forms of life, what I have called elsewhere "the weak biological universe" (Dick 2000a), as advocated by Ward and Brownlee (2000). Rather, the postbiological universe is one in which the *majority* of intelligent life has evolved beyond flesh and blood intelligence, in proportion to its longevity, L.

SETI practitioners often state that ETI would be much older than terrestrial intelligence (TI), and that therefore SETI programs stand to inherit much knowledge and wisdom of the universe. However they assume that ETI will just be some more advanced form of TI. This may be an excellent case of what Arthur C. Clarke calls "a failure of imagination" because it represents a failure to take into account cultural evolution. If civilizations are billions of years older than TI, or even millions of years older, our experience with the evolution of intelligence on Earth indicates that biological evolution would have carried such civilizations far beyond TI in terms of mental capacity. Moreover, as argued below, if civilizations are even thousands of years older than TI, cultural evolution would likely have also resulted in artificial mental capacities beyond TI, concluding in a postbiological universe. There are thus three scientific premises in the arguments for a postbiological universe 1) the maximum age (A) of ETI is several billion years; 2) the lifetime (L) of a technological civilization is >100 years and probably much larger; and 3) in the long-term, cultural evolution supersedes biological evolution, and would have produced something far beyond biological intelligence. If that is the case, the chances of success for standard SETI programs may be greatly reduced, or at least altered, and our place in the universe may be quite different from anything envisioned except in science fiction. We approach each of these premises in turn.

The Maximum Age of Extraterrestrial Intelligence (A)

Cosmic evolution (Delsemme 1998; Chaisson 2001) is our guide to the maximum age (A) of an extraterrestrial civilization. Recent results from the Wilkinson Microwave Anisotropy Probe (WMAP) place the age of the universe at 13.7 billion years, with one percent uncertainty, and confirm the first stars forming at about 200 million years after the Big Bang (Bennett et al. 2003; Seife 2003). Although these first stars were very massive—from 300 to 1,000 solar masses—and therefore short-lived, it is fair to assume that the oldest Sun-like stars formed within about one billion years, or about 12.5 billion years ago. By that time enough heavy element generation and interstellar seeding had taken place for the first rocky planets to form (Delsemme 1998, 71, Larson and Bromm 2001). Then, if Earth history is any guide, it may have taken another five billion years for intelligence to evolve. So, some six billion years after the Big Bang, one could have seen the emergence of the first intelligence. Accepting the WMAP age of the universe as 13.7 billion years, the first intelligence could have evolved seven and a half billion years ago. By the same reasoning, intelligence could have evolved in our galaxy four billion to five billion years ago, since the oldest stars in our galaxy formed about 10 billion to 11 billion years ago (Rees 1997).

These conclusions are essentially in line with those of a number of other astronomers. Using similar reasoning Norris (2000) argued that the median age of an extraterrestrial civilization is 1.7 billion years, assuming that civilizations born 5 billion years ago are now dying off because the 10 billion year lifetime of a solar type star has reached its end. (This assumption is perhaps pessimistic, given that a civilization more than a billion years old may well have found a way to escape its star system.) Based on the peak of the cosmic rate of carbon production in stars, Livio (1999a, 1999b) concluded the first civilizations would emerge when the universe was about 10 billion years old, or 3.7 billion years ago assuming the WMAP age of the universe. Kardashev (1997) concluded that cosmological models yield an age for civilizations of six billion to eight billion years. Kardashev also pointed out that the youngest and less developed civilizations would be most distant from us, while the oldest and most developed civilizations would be nearest to us. Thus all lines of evidence converge on the conclusion that the maximum age of extraterrestrial intelligence would be billions of years, specifically, A ranges from 1.7 billion to 8 billion years. Even uncertainties of a billion years would not affect the argument for taking seriously cultural evolution.

The Lifetime of a Civilization (L)

But do civilizations really reach this age? Not necessarily. The maximum A of ETI is mitigated by L, the lifetime of a technological civilization. We recall that the Drake Equation (Figure 1) consists of astronomical, biological, and cultural parameters, that L is the determining factor to the extent that N (the number of technological civilizations) approximates L, and that we know almost nothing about L. This is why values of L vary widely to the despair of many who are genuinely interested in the chances of detecting ETI. Sagan, Drake, and others generally assigned L values in the neighborhood of a million years, and even some pessimists admitted 10,000 years was not unlikely (Dick 1996, 441). Nevertheless, the only data point for L is ourselves, and if L is defined as a radio communicative technological civilization, all we may conclude from this datum is that L is at least 100 years. Beyond that single data point, L is a matter of whether one is optimistic or pessimistic about the survival of civilization. This is hardly an objective parameter even for a single individual; SETI pioneer Joseph Shklovskii, for one, became a pessimist at the end of his life, due in part to political events in the Soviet Union.

Difficulties notwithstanding, is there any more that can be said about L? What about an upper bound? One sometimes hears that civilizations are inherently unstable, that they have risen and fallen many times on Earth, and that therefore an upper bound for L is several thousand years. But what is really relevant is not the longevity of any single historical civilization on Earth, but that terrestrial civilization as a whole is still alive and well after five millennia of ups and downs known as "human history." It seems likely that technological civilization can last much longer, barring man-made catastrophes such as nuclear war and natural catastrophes such as mass extinctions. That a man-made catastrophe could totally wipe out civilization seems unduly pessimistic, despite the controversial results of nuclear winter scenarios (Turco and Toon, et al. 1983). It seems likely that even in a nuclear world war, some corner of civilization would survive robustly enough that the slow climb of technological evolution would not have to start over again, much less recapitulate the even slower climb of cultural evolution from the cave, or the biological evolution of complex life.

Natural phenomena such as mass extinctions, supernovae, and gamma ray bursters are more problematic for civilization. Norris argued that the latter two events should extinguish all life on planets at intervals of about 200 million years, a conclusion at variance with what we observe on Earth (Norris 2000). A more refined study of gamma ray bursters (Scalo and Wheeler 2002) indicates events of potential biological significance, though not necessarily catastrophic, every 10 million years or so. Current data indicates that a mass extinction from an impacting comet or asteroid serious enough to precipitate the collapse of civilization might occur every 300,000 years (Chapman and Morrison 1989; Raup 1992; Chapman and Morrison 1994). Mass extinctions similar to those that destroyed the dinosaurs, and would probably destroy *Homo sapiens*, have taken place on the order of tens of millions of years (Raup 1992; Becker 2002). Assuming that mass extinctions and other cosmic catastrophes could not be overcome, L would be between 100 years and tens of millions of years. If human ingenuity could overcome such natural catastrophes, or (in the case of mass extinctions) if human civilization has evolved far enough that even a small but technologically capable part of human civilization has been transported self-sufficiently to space, then L could conceivably approach A, which is billions of years. Surveying the vast range of possible catastrophes, Leslie (1996) has estimated that civilization has a 70 percent chance of lasting five more centuries, and believes that if it lasts that long, it could last millions of years.

Necessarily, none of this has the certainty of rigorous deduction. But the possibility of long lifetimes for technological civilizations leads us to explore the likely evolution and nature of such civilizations. It is clear that *biological* evolution, by definition, over the course of millions of years would produce nothing but more advanced biology. Consider what happened to the genus *Homo* in two million years of biological evolution on Earth. Where will we be in another two million years of biological evolution? And what would a billion-year-old terrestrial civilization be like? Possibly the minds of those comprising such a civilization would have evolved significantly beyond *Homo sapiens*. Possibly a similar process would take place for any extraterrestrial intelligence with serious implications for what we normally envision as the biological universe full of communicating civilizations. I say "possibly" because although *knowledge* surely would have increased in both cases, we know so little about the biological evolution of intelligence on Earth (Mithen 1996; Deacon 1997; Parker and McKinney 1999) that its future is unpredictable.

But the important point is that, even at our low current value of L on Earth, biological evolution by natural selection is already being overtaken by cultural evolution, which is proceeding at a vastly faster pace than biological evolution (Dennett 1996). Technological civilizations do not remain static; even the most conservative technological civilizations on Earth have not done so, and could not given the dynamics of technology and society. Unlike all the other parameters in the Drake Equation, L is a problem of cultural evolution, and cultural evolution must be taken into account no less than astronomical and biological evolution. It must be treated as an integral part of cosmic evolution, in direct proportion to L, the age of the civilization. And unlike biological evolution, L need only be thousands of years for cultural evolution to have drastic effects on civilization.

Cultural Evolution

Because the nature of technological civilizations on time scales ranging from hundreds to billions of years reduces to a question of cultural evolution, we must turn to the social and behavioral sciences for insight. These disciplines have shown embryonic interest in the implications of successful SETI (Billingham et al. 1999; Harrison et al. 2000), but have yet to tackle the problem of cultural evolution in a cosmic context. This is hardly surprising;

compared to astronomical and biological evolutions, our understanding of how culture evolves even on Earth is rudimentary. In the past, social scientists have posed two broad models of cultural evolution: the Spencerian, which views society as evolving "through well-defined stages, progressing from chaos to order, from simple to complex, from lower to higher"; and the Darwinian, which posits no particular direction, provides an explanatory framework rather than a historical generalization, and is evolutionary rather than revolutionary (Fellner 1990).

Most social scientists have judged the Spencerian model as too simplistic, but after a long lapse since Darwin's own ideas on cultural evolution detailed in *The Descent of Man* (Richerson and Boyd 2001), Darwinian models of cultural evolution have proliferated in recent decades and have been highly controversial. "Darwin's dangerous idea," as the philosopher Daniel Dennett calls it, posits that the same general evolutionary principles that apply to biology may also apply to culture, though with a mix of mechanisms including the Spencerian inheritance of acquired characteristics as well as those related to natural selection (Dennett 1996). The challenge is in the details of "Darwinizing culture," and elucidating how genes and culture may coevolve. Because the foundation and engine of cultural evolution are human psychology, behavior, cognition, and the transmission of ideas, they must serve as the basis for any theory, though they are notoriously difficult to characterize in individuals, much less in the aggregate.

Among the first modern Darwinian theories of human behavior was sociobiology (Wilson 1975), "the systematic study of the biological basis of all social behavior." Sociobiology has generated bitter disputes as a Darwinian extension from the realm of biology to that of culture (Segerstrale 2000). No less controversial have been related attempts (Lumsden and Wilson 1981; Wilson 1998) to use the idea of gene-culture coevolution to span the natural and social sciences. Cavalli-Sforza and Feldman (1981) pioneered a distinctive approach to gene-culture coevolution that makes use of population genetics. One of the more sophisticated Darwinian models of cultural evolution in this vein, termed the "dual inheritance" theory (Boyd and Richerson 1985), uses population genetics to construct simple mathematical models of how cultural evolution works. The authors recognize, however, that their system cannot yet make quantitative predictions, but can only clarify the relationships between cultural transmission and other Darwinian processes. A better known, if less rigorous, Darwinian model is Dennett's "Universal Darwinism," wherein he argues that Darwinism applies to humans at many levels—mind, language, knowledge, and ethics (Dennett 1996). When applied to knowledge and its transmission, Dennett's brand of Universal Darwinism leads to the field of "memetics," based on Dawkins's idea (1976) that culture evolves via memes in the same way that biology evolves with genes. Despite a number of books and a *Journal of Memetics*, even memetic enthusiasts realize the field is far from a real science (Aunger 2000).

All such Darwinian models of cultural evolution have considerable problems. Indeed, for historical reasons many social scientists still resist evolutionary hypotheses of culture altogether (Lalande and Brown 2002, 28). It is possible that some synthesis of sociobiology, gene-culture coevolution, and memetics, along with related Darwinian models like behavioral ecology and evolutionary psychology, will some day provide a widely accepted theory or mechanism for cultural evolution (Lalande and Brown 2002; Segerstrale 2000). It is also possible that the concept of "emergence" will play a role, that culture or its components (toolmaking, language, agriculture, technology, and so on) are emergent phenomena that will be explained in terms of agents, rules and "pruning relations" in the way that the origin of life and the origin of consciousness may someday be explained as emergent phenomena (Morowitz 2002). But for now a widely accepted theory or mechanism of cultural evolution is lacking.

Still, theoretical and empirical studies of cultural evolution hold hope for a science of cultural evolution in the same way there is currently a well-developed science of biological evolution. In the context of extraterrestrial life, even a theory of universal biological evolution does not yet exist, much less a theory of universal cultural evolution. And even if a theory of cultural evolution existed, such models (short of Asimovian psychohistory) would lack the power to predict the future of our own culture, much less those of extraterrestrials. While galactic, stellar, and planetary evolution may be predicted to some extent based on physical principles, biological evolution cannot be predicted based on natural selection, and the prediction of our cultural evolution is not even contemplated except in the long-term context of the fate of the universe (Ward and Brownlee 2003). And while there is no lack of purely descriptive accounts of terrestrial cultural evolution, such descriptions also lack explanatory power or the predictive power needed to answer our question about the future of cultural evolution.

Lacking a robust theory of cultural evolution to at least guide our way, and "wildcard" events notwithstanding, we are reduced at present to the extrapolation of current trends supplemented by only the most general evolutionary concepts. Several fields are most relevant, including genetic engineering, biotechnology, nanotechnology, and space travel. But one field—artificial intelligence—may dominate all other developments in the sense that other fields can be seen as subservient to intelligence. Biotechnology is a step on the road to AI, nanotechnology will help construct efficient AI and fulfill its goals, and space travel will spread AI. Genetic engineering may eventually provide another pathway toward increased intelligence, but it is limited by the structure of the human brain. In sorting out priorities, I adopt what I term the central principle of cultural evolution, which I will refer to as the Intelligence Principle: *the maintenance, improvement and perpetuation of knowledge and intelligence is the central driving force of cultural evolution, and that to the extent intelligence can be improved, it will be improved*. At the level of knowledge, we see this principle in daily operation as individuals, groups, and societies attempt to maximize their knowledge in order to gain advantage in the world around them, an endeavor in which some succeed better than others. Better education, better information, and better technology are generally perceived as advantageous to the individual, group, or society—an understanding recognized in the aphorism "knowledge is power." At the species level, which is the meaning I primarily refer to here, intelligence is related to the size and structure of the brain of *Homo sapiens sapiens*, a capacity that has not changed in 100,000 years, and that led to the "big bang of human culture 60,000–30,000 years ago" (Mithen 1996). In hominid biological evolution the increased brain size and intelligence of *Homo sapiens sapiens* allowed it to outcompete other hominid species and dominate the planet. In the cultural evolution of the species, the same will hold true. Failure to improve intelligence, resulting in inferior knowledge, may eventually cause cultural evolution to cease to exist in the presence of competing forces like AI. In Darwinian terms, knowledge has survival value, or selective advantage, as does intelligence at the species level, a fact that may someday be elucidated by an evolutionary theory of social behavior, whether "group selection" as recently applied to religion (Wilson 2002), selfish gene theory, evolutionary epistemology (Bradie 1986), or some other Darwinian model. The Intelligence Principle implies that, given the opportunity to increase intelligence (and thereby knowledge), whether through biotechnology, genetic engineering, or AI, any society would do so, or fail to do so at its own peril.

The Intelligence Principle is a hybrid between the Spencerian and Darwinian models of cultural evolution in the sense that it does not have well-defined stages, but is evolutionary and implies a direction toward greater intelligence. Because it is governed by mind, the process is goal-oriented. Culture may have many driving forces, but none can be so fundamental, or so strong, as intelligence itself.

Turning, then, to the field of AI as a striking example of the Intelligence Principle of cultural evolution, we find quite astounding predictions. As Dyson (1997, 25) has pointed out, ever since the Industrial Revolution, there has been concern about the rise of the machines and their relation to humans. Butler (1863) wrote "[w]e find ourselves almost awestruck at the vast development of the mechanical world, at the gigantic strides with which it has advanced in comparison with the slow progress of the animal and vegetable kingdom. We shall find it impossible to refrain from asking ourselves what the end of this mighty movement is to be . . . . The machines are gaining ground upon us; day by day we are becoming more subservient to them; more men are daily bound down as slaves to tend them; more men are daily devoting the energies of their whole lives to the development of mechanical life." After a century of progress in machine development and the increasing convergence between machine and life that Dyson describes, MacGowan and Ordway (1966) argued that, "[a]ny emerging intelligent biological society which engages in the development of highly intelligent automata must resign itself to being completely dominated and controlled by automata. The only means of preventing domination by intelligent artificial automata would be to make them distinctly subnormal in intellectual capacity, when compared with the biological society, and to destroy them or clear their memories at regular intervals." The possibilities of AI played a substantial role in MacGowan and Ordway's volume on extraterrestrial intelligence, but those possibilities were completely overshadowed by the publication of Shklovskii and Sagan (1966) in the same year. Although the last chapter of Shklovskii and Sagan's volume was on "Artificial Intelligence and Galactic Civilizations," the AI thesis was very general and lost in the midst of the exciting—and at the time more verifiable and realistic—implications of the other chapters, which assumed biological beings. Over the last 40 years, SETI has focused almost exclusively on the biological paradigm, especially the radio SETI technique, as opposed to a postbiological paradigm (MacGowan and Ordway 1966, 265; Shklovksii and Sagan 1966, 281–288).

The study of AI was rudimentary in 1966, but MacGowan and Ordway's idea as applied to humans has been broached in subsequent years as the field of AI developed. One of the most forward-thinking scholars in the field is Hans Moravec, a pioneer in AI and robotics at Carnegie-Mellon. Already in 1988 in his book *Mind Children: The Future of Robot and Human Intelligence*, Moravec predicted that "[w]hat awaits is not oblivion but rather a future which, from our present vantage point, is best described by the words 'postbiological' or even 'supernatural.' It is a world in which the human race has been swept away by the tide of cultural change, usurped by its own artificial progeny." Within the next century, he predicted, our machines "will mature into entities as complex as ourselves, and eventually into something transcending everything we know—in whom we can take pride when they refer to themselves as our descendants. Unleashed from the plodding pace of biological evolution, the children of our minds will be free to grow to confront immense and fundamental challenges in the larger universe." (Moravec 1988, 1; Moravec 1999). Just as there may have been a genetic takeover when RNA or DNA took over from some more primitive system like clay, Moravec foresees a robotic takeover. This assumes the strong AI position that it is possible to construct intelligent machines functionally equivalent to human intelligence, a point of considerable contention (Searle 1980; Tipler 1994, ch. 2). It seems reasonable to assume, however, that the strong AI position will prove increasingly true in direct proportion to the time available for further developments in the field—time that extraterrestrial civilizations, if any, will have already had.

Another thinker who came to a similar conclusion in the terrestrial context is inventor Ray Kurzweil, a pioneer in AI who has been critical in bringing voice-recognition machines to the commercial market. In *The Age of Spiritual Machines: When Computers Exceed Human Intelligence*, Kurzweil, (1999) also adopting the strong AI claim, sees the takeover of biological intelligence by AI, not by hostility, but by willing humans who have their brains scanned, uploaded to a computer, and live their lives as software running on machines. In his view, human intelligence will be left behind. Physicist Frank Tipler, well known for his work on the anthropic principle and the Fermi Paradox, has also weighed in on this subject. After a review of the arguments for and against strong AI, Tipler (1994) concluded that "the evidence is overwhelming that in about thirty-odd years we should be able to make a machine which is as intelligent as a human being, or more so." Tipler does not necessarily foresee a takeover, but believes that such machines will enhance our well-being. And he ties these ideas to the resurrection of the dead and an entire cosmotheology.

It may well be that Moravec, Kurzweil, and their proponents underestimate the moral and ethical brakes on technological inertia; after all, the abortion controversy in the United States pales in significance with the replacement of the species. And Fukuyama (2002) argues strenuously against a possible "posthuman future" that he sees stemming from advances in the brain sciences, neuropharmacology and behavior control, and the prolongation of life and genetic engineering. He argues for the regulation of biotechnology to preserve human nature, and biotechnology is relatively tame compared to the possibilities of AI. But such objections fail to take into account cultural evolution, and may lose their impact over the longer term,

Table 2. Lifetime of a Technological Civilization and Effects on SETI.

L (Years)	Stage of Cultural Evolution	Effect on SETI
< 100	Biological	Civilizations scarce but comparable level—EM SETI possible
100-1000	Machine/Biology Hybrid (Cyborg)	Hybrid techniques
> 1000	Postbiological	Advanced artificial intelligence—Direct EM SETI unlikely

as the Intelligence Principle asserts itself. If we consider cultural evolution over the last millennium, especially as regards science and technology, who would have predicted space travel, genetic engineering, and nanotechnology? No one could have, because the foundational concepts were not in place. This might lead us to conclude that in another millennium there will be important concepts that we have no inkling of now. This is undoubtedly true. But barring a landmark transformation in human thought comparable to the origins of western science over the next thousand years, we are set on a course that will still be playing out in 3001, with AI still a predominating factor. When one considers the accelerating pace of cultural evolution as we enter the third millennium of our era, radical change of the sort foreseen by Moravec and Kurzweil does not seem so far-fetched. Just as Thomas Aquinas had a failure of imagination almost a millennium ago, so do we.

We thus come to a startling conclusion. Based on what experts see happening on Earth, L need not be five billion, one billion, or a few million years. It is possible that a postbiological universe would occur if L exceeds a few hundred or a few thousand years, where L is defined as a technological civilization that has entered the electronic computer age, which on Earth was almost simultaneous with the usual definition of L as a radio communicative civilization. If L is less than a few hundred years, less than the time it takes for a technological civilization to conceive, design, construct, and launch their intelligent machines, we do not live in a postbiological universe. If L is between 100 and 1,000 years, a transition zone may result populated by human/machine symbiosis, sometimes referred to as "cyborgs" (Dyson 1997; Ward and Rockman 2001; Gray 2002), and genetically engineered humans. But if L is greater than 1,000 years, we almost certainly will have made that transition to a postbiological universe (Table 2). "Interstellar humanity" (Dick 2000b) remains valid if we expand our definition of "humanity" to our artificial progeny, Moravec's "mind children." As for the present, on the time scales of the universe, this means that we are in the minority; the universe over the billions of years that intelligence has had to develop will not be a biological universe, but a postbiological universe. Biologically based technological civilization as defined above is a fleeting phenomenon limited to a few thousand years, and exists in the universe in the proportion of one thousand to one billion, so that only one in a million civilizations are biological. Such are the results of applying the Intelligence Principle, and the insights of Moravec, Kurzweil, and Tipler among others, to the entire universe using Stapledonian thinking.

The Nature of the Postbiological Universe and its Implications for SETI

What would a postbiological universe be like? What is artificial intelligence *doing* out there? And what does it mean for SETI? Speaking of Earth, Moravec believed that “A postbiological world dominated by self-improving, thinking machines would be as different from our world of living things as this world is different from the lifeless chemistry that preceded it. A population consisting of unfettered mind children is quite unimaginable” (Moravec 1988, 5). Even more unimaginable, then, would be the activities of artificial intelligence in the universe. But, in the tradition of Stapledon, and guided by the Intelligence Principle, let us try.

Although one cannot, and need not, specify morphological details of postbiologicals, we can assess with some confidence their general characteristics. Complex intelligent postbiologicals—which we can assume over the time intervals dealt with here—would have the capability of repair and update, capabilities facilitated by their modularity. The so-called von Neumann machine is able to reproduce better versions of itself. Part of this reproduction is the improvement of intelligence; unlike humans this intelligence is cumulative in the sense that the sum total of knowledge in the parent machine is passed on to the next generation, conferring effective immortality for the machine’s most important characteristic. The immortality of postbiologicals is enhanced by their increased tolerance to their environment, whether it be vacuum, temperature, radiation, or acceleration (MacGowan and Ordway 1966).

Immortal postbiologicals would embody the capacity for great good or evil over a domain that dwarfs biological domains of influence. There are admittedly deep questions of the nature of “good,” “evil,” and “morality” in the context of artificial intelligence in the universe (Ruse 1985). But if the

Intelligence Principle holds, postbiologicals are driven by the improvement of knowledge and intelligence. How they would use these qualities presumably remains a value question no less than for humans. One notable interpretation from science fiction is Asimov's robot series, where select robots traverse the galaxy trying to influence events in a positive way, subject to the famous Laws of Robotics. But another interpretation is that AI could be motivated by darker purposes, whether through the programming of its parent biologicals or through its own evolution. Saberhagen evokes this scenario in his Berserker series, where Berserkers are not quite AI, but are near-sentient death machines programmed for their prime directive to seek out and destroy life wherever it may hide. As Brin has pointed out, such deadly probes, whether intelligent or not, are an eerie solution to everything we observe, including "the Great Silence" as so far determined by all SETI programs (Brin 1983).

It is notable that Asimov's robots are human descendants, since his universe has no extraterrestrials, and that his robots are still to some extent controlled by humans according to the second law, and can allow no harm to come to humanity according to the zeroth law. It is also notable that in Arthur C. Clarke's universe, which is full of extraterrestrial intelligence, artificial intelligence plays very little role—with the exception in *2001: A Space Odyssey* of HAL, a disastrous postbiological that violated Asimov's three laws by harming humans. It would seem that Clarke may have had a failure of imagination when it comes to the potential role of AI in the universe, or that he saw AI as a passing part of evolution: in his earlier novel *The City and the Stars* (1956), humans teamed with other galactic civilizations to build a disembodied intelligence, a pure mentality that would seem to be beyond the stage of AI.

This raises a valid point: on the principle that nothing in the universe remains static, postbiologicals would continue to be subject to cultural evolution. AI may not be the ultimate emergence of cultural evolution, and Morowitz (2002) has suggested that "spirit" could be an emergent phenomenon beyond AI. Where cultural evolution would ultimately lead one cannot say, except that ultimate entities might have characteristics approaching those we ascribe to deities: omniscience, omnipotence, and perhaps the capability of communication through messenger probes. Stapledon himself has envisioned such a being in *Star Maker*, although not a product of cultural evolution via artificial intelligence. Thus, our reflections on postbiologicals lead to a possibility that some might characterize as cosmotheology (Dick 2000c).

Given the characteristics of immortality, increased tolerance to their environment, capacity for action on a large scale, and an intelligence far superior to our own, what are the implications of the postbiological universe for SETI? First, there is the problem of search space. Environmental tolerance and availability of resources beyond the planetary realm means that SETI searches for postbiologicals need not be confined to planets around Sun-like stars, nor to planets at all (Shostak 1998, 201; Tough 2002). Indeed postbiologicals probably would "prefer" not to be so confined. Artificial intelligence, or their robotic surrogates, could roam the galaxy as reproducing von Neumann machines (Tipler 1985), Bracewell probes (Bracewell 1975), or smart microprobes (Tough 1998). Roaming intelligent probes might also lead to an AI version of the Fermi Paradox, but with novel possibilities for solution, since postbiological "psychology" may be very different from the psychology of biologicals.

Secondly, there is the question of the nature of the signal. Postbiologicals could be communicating with each other via electromagnetic signals, but the Intelligence Principle tending toward the increase of knowledge and intelligence renders it unlikely they would wish to communicate in such a way with embryonic biologicals like humans. Shklovskii and Sagan pointed out that the long lifetimes of artificial intelligence "could be very advantageous for interstellar contact among advanced communities. The sluggishness of two-way radio communication over interstellar distances tends to make such contact unsatisfactory for beings with lifetimes measured in decades. But for very long-lived beings, such communication would be much more interesting" (Shklovskii and Sagan 1966, 487). What Shklovskii and Sagan left unsaid was that this means that short-lived biologicals such as ourselves might be reduced to intercepting communications of postbiologicals; attempts to do this might lead to a new sense of what the "magic frequencies" are. Intercepting such signals at interstellar distances would undoubtedly be more difficult than detecting a signal directed at us. But if one of the activities of postbiologicals is to study emerging biologicals, as terrestrial anthropologists study our own roots, they may be closer than we think. Indeed, as the products of technology, the Intelligence Principle of cultural evolution implies that, even if they did not wish to communicate with us, postbiologicals would incessantly attempt to increase their knowledge of emerging cultures and their perhaps unique pathways in the development of science, technology, and mathematics.

Thirdly, the Intelligence Principle leads us to conclude that postbiologicals might be more interested in receiving signals from biologicals than in sending them. This conclusion should lead us to place new emphasis on message construction, to explore the implications for message construction if the intended recipients are AI, including the optimal mode of representation to be used with postbiologicals in contrast to biologicals. In addition to increasing their knowledge of the physical and biological universe, would postbiologicals also be interested in spiritual principles, altruism, and the arts, as some have recently proposed for extraterrestrial biologicals? (Vakoch 1998, 1999; Ringwald 2001). This is tantamount to asking if postbiologicals would be interested in cultural evolution; as products of cultural evolution themselves, this seems highly likely, and with this conclusion cultural evolution comes full circle in a cosmic context.

Finally, the vast disparity in age between postbiologicals and biologicals highlights what has been called the Incommensurability Problem. It is entirely possible that the differences between our minds and theirs are so great that communication is impossible.

With a better understanding of the role of cultural evolution in cosmic evolution, it seems clear that the L parameter is a double-edged sword for SETI. If L is large, extraterrestrials may have evolved through biological or cultural evolution, beyond human understanding. If L is small, the chances of communication increase because our mental capacities might be more comparable, but N becomes much smaller, and the chances of finding any scarce civilizations are much smaller. Here, in the Siren call of SETI, we are caught between Scylla and Charybdis.

All of these conclusions, and the possibility of a postbiological universe in general, point to the need to place AI research in a cosmic context. AI and SETI, after all, have much in common with their interest in the nature of intelligence. And although the difficult problem of the definition of intelligence is beyond the scope of this article, the relation of biological and postbiological intelligence gains greater urgency with the prospect that cultural evolution may have already produced artificial intelligence throughout the universe. With the symbiosis of SETI and AI, SETI expands its possibilities into new phase space, and the study of the long-term future of AI becomes more than idle speculation.

Summary and Conclusions

We have applied two methodological principles in this paper: 1) long-term Stapledonian thinking is a necessity if we are to understand the nature of intelligence in the universe today, and 2) cultural evolution must be seen as an integral part of cosmic evolution and the Drake Equation. We have accepted the strong AI theory that it is possible to construct artificial intelligence equivalent to, or superior to, humans, and adopted the Intelligence Principle that the improvement and perpetuation of intelligence is a central driving force of cultural evolution. Applying these principles to the universe, we have argued that if the lifetime of technological civilizations typically exceed 1,000 years, it is likely that we live in a postbiological universe. The argument makes no more, and no fewer, assumptions about the probability of the evolution of intelligence, or its abundance, than standard SETI scenarios; it argues only that if such intelligence does arise, cultural evolution must be taken into account, and that this may result in a postbiological universe. As a by-product of the discussion, we point out that even if we live in a biological universe, the extraterrestrials that compose the biological universe would be millions, if not billions, of years older than us.

Whether biologicals or postbiologicals, we conclude that the implications for SETI strategies are profound. Biologicals that are part of a civilization millions or billions of years old may or may not still be using electromagnetic technology for SETI, calling for new strategies (Tough 2000). Postbiologicals would not be confined to planetary surfaces, they might be more likely to roam the universe than to send signals, they might be using electromagnetic technology for communication among themselves rather than with others, and they would be more likely to receive than to send messages. Lacking a theory of cultural evolution on Earth, we are unable to predict the cultural evolution even of our own species in the near future. Lacking a knowledge of advanced biological or postbiological motivations, we are unable to predict the nature of civilizations millions or billions of years older than ours. Still, the likelihood of Darwinian-type mechanisms at work in cultural evolution throughout the universe forces us to consider the real possibility—perhaps amounting to probability—of a postbiological universe, and calls for a sweeping reconsideration of SETI assumptions and strategies.

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