

## Directed Panspermia and the Fossil Record

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### Abstract

Life in the universe may be common, but searches for extraterrestrial intelligences have been heretofore fruitless. If an alien intelligence has intervened in the evolution of life on Earth, there may be evidence in the fossil record. Discussions of panspermia, evolution, and alien intelligence tend to be ridden with fallacies, including the idea that intelligence alone is sufficient for interstellar travel, or the idea that panspermia must occur through the propagation of seeds or spores. Other fallacies include the conception of alien life forms as friendly neighbors and the implicit assumption that the human ability to comprehend and understand the universe is unlimited. The event in the terrestrial fossil record most suggestive of alien intervention is the Cambrian Explosion, a period from about 540 to 520 million years ago when there was a relatively rapid increase in animal diversity and abundance. The unique nature of this period calls into question if purely naturalistic evolutionary mechanisms had the creative power to effect the dramatic changes observed in the fossil record. Technologies that spread life throughout the galaxy using robots and artificial intelligence have moved from the realm of speculative fiction to inevitable extrapolations of existing trends. Given sufficient information and energy, anything permitted by the laws of nature is possible.

**Key words:** Cambrian Explosion, Alien Intervention, Panspermia, Extraterrestrial Intelligence, Directed Evolution

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### **1. Fermi's Paradox**

*Fermi's Paradox* is the observation that there is an apparent contradiction between the high probability of life in the universe and the lack of evidence for human contact with, or observation of, any alien species of life. The Paradox is named after the physicist Enrico Fermi (1901-1954). The origin of the Paradox dates to a luncheon held in the year 1950 where the possibility of extraterrestrial life was discussed. In apparent response to a claim that the vastness of both space and time made intelligent, spacefaring civilizations common in the galaxy, Fermi reportedly questioned "where are they?" In other words, given the vastness of both space and time, if intelligent life in the universe is common, there should be obvious evidence of its presence on Earth. But that evidence is scarce and questionable; it exists only in the form of apocryphal anecdotes and myths, if at all (1).

Gray (2) has argued convincingly that Fermi's Paradox is misnamed, because it did not originate with Fermi. Fermi never published any work on extraterrestrial life or interstellar travel. The term "Fermi Paradox" did not appear in print until the year 1977, more than twenty years after Fermi's death. It is also possible that when Fermi posed the question "where is everybody," he may have been questioning the feasibility of interstellar travel, not the existence of extraterrestrial life. Gray (2) attributed the Fermi Paradox to Hart (3) and Tipler (4), who both argued that intelligent, spacefaring alien beings do not exist, and that human beings have the only technological civilization in the Milky Way Galaxy. Gray (2) concluded that the Fermi Paradox is not a paradox, but an argument that depends on "many speculations which are not known to be true" (p. 197).

Other writers have been more optimistic regarding the possible existence of alien life and interstellar travel. Newman and Sagan (5) argued that "Earth is uncolonized not because interstellar spacefaring societies are rare, but because there are too many worlds to be colonized in the plausible lifetime of the colonization" (p. 293). Sagan and Newman (6) warned that claims of a unique status for human beings smack of anthropocentrism, bucking a long-established historical trend in science of invalidating anthropomorphic claims.

The reason that extreme and opposing conclusions and viewpoints are found in the scientific literature is that the question of life outside Earth and its propagation through interstellar space is not a question that can be readily subjected to empirical corroboration or falsification. While it has been estimated that the Milky Way galaxy contains 300 million worlds that are potentially habitable (7), we simply do not know under what conditions life can originate or spread, nor what evidence of an advanced, non-human technological civilization would look like. Sagan and Newman (6) pointed out that it's "possible that the Milky Way Galaxy is teeming with civilizations as far beyond our level of advance as we are beyond the ants, and paying us about as much attention as we pay to the ants."

Panspermia is the theory that life did not begin on Earth, but exists throughout the galaxy, if not the cosmos, and was seeded on Earth and other locations by either natural or artificial mechanisms. The first invocation of panspermia is often credited to the ancient Greek philosopher, Anaxagoras (c. 500-428 BC), who attributed the origin of both animals and plants to "seed" that fell "from heaven to earth" (8, p. 268-269). However, this interpretation is generous. The primary source exists only in ambiguous fragments.

A thorough history of panspermia is given by Mitton (9), and the material found there need not be reproduced here in its entirety. In recent history, the first

cogent scientific arguments that lent credence to panspermia were made by Thomson (10) and Arrhenius (11). Reasoning by analogy, William Thomson (1824-1907, better known as Lord Kelvin) noted that when a volcanic island arises from the sea within a few years it is covered by vegetation. Yet no one argues that life on that island arose spontaneously from inorganic materials, rather it is obvious that it sprang from seeds transported there (10, p. 269). As a general principle, Thomson argued that "life proceeds from life," and as the Earth presumably began as a red-hot molten mass, (10, p. 269), it was probable if not necessary that vegetable life on Earth began through a process of external seeding. The mechanism invoked by Thomson to accomplish this seeding was bombardment by "countless seed-bearing meteoric stones moving about through space (10, p. 269-270). Anticipating criticism, Thomson conceded that the theory of panspermia "may seem wild and visionary," but maintained that "it is not unscientific" (10, p. 270).

The origin of life through abiogenesis continues to be much of a mystery as it was when Thomson (10) wrote (12). Burchell (13, p. 73) pointed out "it is not uncommon in education today to be told earnestly in one classroom that scientists have shown that spontaneous generation of life is impossible, and to be equally earnestly told in another classroom that Darwinian evolution shows that all life on Earth is descended from a common ancestor which just appeared."

Like Thomson (10), Arrhenius noted that all scientific evidence indicated that life could only come from life, and therefore the necessary corollary was that life had been seeded on Earth through panspermia. Arrhenius thought Thomson's conjecture of seed-bearing meteors was problematic and invoked radiation pressure from the Sun and other stars as a mechanism for distributing minute spores throughout both the Solar System and interstellar space. Arrhenius concluded that "all organic beings in the whole universe should be related to one another" (11, p.

229). Corroboration of Arhenius' conception is the modern observation that biological molecules are common and widespread in our galaxy (14).

Wickramasinghe et al. (15, p. 30048) have suggested that life is common throughout the galaxy and constitutes "a single connected biosphere."

*Directed Panspermia* is the theory that the seeding of life on Earth or elsewhere is the result of an intentional effort by an intelligent lifeform. This hypothesis was first described in the scientific literature by Shklovskii and Sagan (16). However the first cogent articulation of the theory was by Crick and Orgel (17). Two lines of possible evidence for alien intervention in the history of life on Earth were suggested by Crick and Orgel (17). First, "the presence in living organisms of elements that are extremely rare on Earth might indicate that life is extraterrestrial in origin" (17, p. 344). Molybdenum is an essential cofactor in several enzymatic reactions, yet relatively scarce on Earth. The second argument is that if life was seeded on Earth by an intentional and intelligent effort, the genetic code should be universal for all terrestrial organisms. "The universality of the code follows naturally from infective theory of the origins of life on Earth" (17, p. 344). Neither of the preceding arguments is conclusive. While it is true that "the standard genetic code is virtually universal among extant life forms" (18 p. 45), if life on Earth arose spontaneously from a common ancestor, or from an ancestor introduced by a natural mechanism, all existing life would also be expected to share a common genetic code.

Life on Earth is approximately 4 billion years old. If there has been intervention, direction, control, or influence by an alien intelligence, this would be a form of directed panspermia. Heretofore, most approaches to searching for signs of intelligent life in outer space have been confined to searching through space (15). "We continue to think the most promising way to search for extra-terrestrial life is to search for radio signals" (19, p. 635). I suggest that we look not just

through space, but also through time by examining the 4 billion year old record of life on Earth to see if there is any evidence suggestive of intelligent intervention.

## 2. Fallacies

### *The Intelligence Fallacy*

In discussions concerning the possibility of extraterrestrial life, it is often implicitly assumed that intelligence alone is enough for an alien life form to develop a technological civilization and the means of interstellar travel. But much more than mere intelligence is necessary.

To develop technology, an organism must have the ability to manipulate and control their environment. Human beings have hands with opposable thumbs that enable us to create and use tools. Dolphins, for example, exhibit intelligence of the same order as humans. They can learn complex tasks, have good memories, and display social skills and empathy. But it is difficult to envisage any future scenario in which dolphins develop space travel. How does a species that lives in water and lacks manipulative organs develop metallurgy? Is space travel possible without metallurgy?

The development of technology also requires social cooperation and collaboration. Man is a social animal. As Aristotle (384-322 BC) noted in *Politics*, only "a beast or a god" can live by themselves (20, p. 55, 1253a). At any time, the existing state of human knowledge represents the culmination of several thousand years of ongoing discovery, refinement, correction, and elaboration. Science advances incrementally through collaboration. Humans are not the only species on Earth that exhibits social behavior. There is a high degree of social cooperation amongst bees and ants. Mammals such as ungulates live in herds. Even fish group together in schools. But in the totality of life on Earth, social cooperation within a

species tends to be the exception rather than the rule. There is no justification for automatically assuming that any intelligent alien species would necessarily be inclined to engage in the social cooperation necessary to develop advanced technology. Intelligence alone is not enough for the development of the technology that would make space travel possible. A life form must also have the ability to physically manipulate and control its environment and a habit of social cooperation.

### *The Seed Fallacy*

Most discussions of panspermia, either natural or directed, presume that life is spread by the propagation of living organisms in some latent form, typically either seeds or spores. This is an anthropomorphic presumption. We presume life must be spread in this manner because human technology cannot create life directly from inorganic materials. This is apt to be a short-lived limitation. Modern science rejects vitalism. *Vitalism* is the theory that living things are inherently different from non-living due to the presence of an unseen life force. Vitalism is an old idea that dates at least to Aristotle. In *De Anima*, Aristotle described the soul as "the principle of animal life" (21, p. 535, 402a), and maintained that "the body cannot be soul," (21, p. 555, 412a). The "last famous champion of modern vitalism" was the German chemist, Georg Stahl (1659-1734). Stahl maintained that the soul shaped the body and controls all mental and physical activity (22, p. 228)

Vitalism was not necessarily a superstitious, irrational, or even unscientific hypothesis in previous ages. The world was observed to be full of occult forces that operated through no visible physical mechanism. Examples included magnetism, electrostatic attraction, and even gravity itself. But modern science rejects vitalism and presumes, as I do, that life is purely mechanical in nature. It is not so much speculation as an extrapolation of progress in the biological sciences to conclude

that human beings will, in the coming centuries, acquire both the knowledge and technology to create living things from inert chemicals. The logical corollary is that directed panspermia by an advanced technology will not occur by the transportation of seeds or spores through interstellar space. Rather, life will be assembled on site. This avoids two difficulties. First, any life developed on an alien world may not be viable on a world that has different environmental conditions. There is little point in planting tomato seeds in the Antarctic, yet mosses, lichens, and many other plants thrive there. Second, the problem of maintaining the viability of seeds or spores through long periods of time, radiation hazards, and extreme heat or cold is entirely avoided.

The preferred method of directed panspermia will be to send out autonomous probes to survey solar systems containing planets that may be suitable sites for life. Presuming an advanced form of artificial intelligence, the robot will survey the system, taking into account pertinent environmental conditions such as temperature and the availability of raw materials. If an autonomous probe has the capability of self-repair and reproduction, an unlimited amount of time will be at its disposal. If conditions are found to be initially unfavorable for life, an entire world or solar system can be engineered to create conditions more conducive to life, even if entire planets have to be moved in their orbits. The key idea here is that with enough information, raw materials, and energy, anything allowed by the laws of physics is possible. And the limitation imposed by the availability of raw elemental materials must be qualified by noting that with energy and information, it should usually be possible to locate and transport any materials that are lacking. And the luxury of unlimited time means that the guiding artificial intelligence need not "get it right" the first time. The development of life can be monitored for a million, ten million, or a hundred million years. After all, the creation of life means more than the formation of a single living organism; it entails the design of a complex web of

interacting and mutually dependent life forms. It is estimated that Earth currently contains approximately 10 million different species of living organisms, all of which to some extent, interact and are mutually dependent.

### *The Colonization Fallacy*

There is an implicit bias or tendency to assume that any advanced alien species with a technological civilization will have a strong impetus to exploration and colonization. This is not necessarily true. Arguably, dispersal enhances the chances of survival, and every living thing must have acquired an instinct for survival. But it does not necessarily follow that any alien species will be aggressive in exploration and colonization. Expansion also carries risks. It increases the possibility of encountering a hostile alien species. And even if there is a survival logic to dispersal, not every group of living organisms consistently behaves in a logical manner. Human history offers many examples of groups that adopted cultural values and practices that were demonstrably inimical to their own physical health, demographic viability, or long-term objective welfare (23).

Aggressive expansion and colonization is not even found universally among different human cultures. Some human cultures have exhibited historical records of aggressive exploration and expansion, but others have not. European colonial powers of the 15th through the 20th centuries, Polynesian voyagers from about 3000 to 1000 BC, and the Mongol Empire of the 13th and 14th centuries underwent periods of aggressive expansion. But other civilizations have focused on stability, self-sufficiency, and internal development. Examples include various dynasties in ancient China and the Japanese Sakoku Period from about AD 1633 through 1853. Thus even if a non-human alien species inhabiting another star system developed the technological means for interstellar travel, it does not necessarily follow that they would engage in colonization or even exploration.

### *The Deification of Man*

At the beginning of Western Civilization, the Greek poet Hesiod (c. 700 BC) described the universe as originating in chaos (24, p.87). The world was dark and disordered, governed by the capricious and arbitrary whims of the gods. Science began when the Ionian Greek philosophers first invoked naturalism in the 6th century BC. The Greeks also invented the principle of demonstration, the idea that truth could be established through a process of logical reasoning (25, p. 16-17). The combination of naturalism with demonstration changed how people viewed the universe. A world that was formerly chaotic and mysterious became a *cosmos*, a place governed by natural law that could be understood. Granted, the Greeks relied largely upon deductive logic rather than systematic empiricism, and it is therefore proper to characterize their science as natural philosophy. But nevertheless the necessary groundwork for the Scientific Revolution of the 16th and 17 centuries was laid in ancient Greece with the principle of demonstration.

Before the universe can be understood it was necessary that it be viewed as a place that can be understood. A universe may be chaotic and unfathomable, but a cosmos is regulated by natural law that can be discovered through a systematic scientific process. However, it is a logical fallacy to implicitly assume that because parts of the cosmos may be comprehensible, the cosmos can be understood in its entirety by the limited human mind. It surely must be the case that there exist natural truths that are forever beyond human comprehension.

The argument can be understood through analogy. Consider the dog. On the spectrum of all animal life, the dog is relatively intelligent. With the exception of chemosynthetic organisms living near hydrothermal vents on the ocean floor, virtually all life on earth depends on light and heat from the Sun. The existence of the Sun and its role in supporting life on Earth is thus not irrelevant to the dog. The

dog depends on the Sun for its life. The dog is aware of the Sun's existence. It can see light and certainly feel the warmth of sunshine. Yet the process of nuclear fusion by which the Sun generates light and heat cannot be understood by a dog. Understanding the nuclear processes that take place within a star requires abstract reasoning, a knowledge of mathematics, and a conceptual grasp of nuclear physics. Dogs quite simply do not have the capacity to understand. Neither do turtles, horses, insects, bacteria, or an endless number of organisms living on Earth that derive their sustenance from nuclear fusion in the Sun.

We accept that all living organisms on Earth have limited mental capacities, yet do not freely acknowledge the obvious corollary: that human beings are also limited. We have committed the logical fallacy of special pleading: that of all of the ten million species of living things on Earth, human beings alone have an unlimited potential to comprehend the mysteries of nature and the cosmos. The pill is bitter to swallow but inescapable. Certain important questions, perhaps including the origin of the universe and life, will remain forever beyond human comprehension. We remain forever shackled in Plato's Cave, doomed to sense only shadows, unable to directly perceive the brilliance of absolute reality.

### *The Friendly Neighbor Fallacy*

Human beings have a tendency to assume that any intelligent alien life form capable of creating an advanced technology will automatically embrace human values of peace, cooperation, and universal brotherhood. On the contrary, a life form may be more likely to view all alien life as an existential threat to its existence.

At this time, we are not aware of a single example of life outside the Earth, let alone an intelligent and technological species of alien life. Yet it is surely difficult to imagine any species of living thing originating and evolving in the absence of

other life forms. We have limited examples on Earth in the form of chemosynthetic organisms, lithotrophs, and extremophiles. But most life exists as part of an ecological system, where organisms interact. It follows that nearly all living things experience competition for resources and survival. In Darwin's words, "there is a frequently recurring struggle for existence" (26, p. 5). Or, in the poet's words, nature is "red in tooth and claw" (27, p. 302). It has been estimated that approximately 99 percent of all the species that have ever lived on Earth are now extinct. No other species on Earth has any discernible regard for human welfare, and the entire history of the human race is one of interminable slaughter within our species. In human history "when less advanced societies drew the attention of those more advanced, the consequences for the former were seldom agreeable" (28).

It is difficult to imagine any alien species arising in a context where all living organisms exist in an idyllic, utopian Garden of Eden, absent any competition, death, or extinction. Therefore any intelligent alien form of life must know that any other form of life, including human beings, is a potential threat. Logic and experience compels the conclusion that contact with an advanced alien species could result in extinction. Because the outcome of extinction is so grave, there need only be a finite possibility of a negative outcome, not a probability, to justify avoidance of contact. On the other hand, there potentially is much knowledge to be gained through contact with an alien species. The logical strategy therefore is surreptitious observation. Observe and learn from another species as much as possible, while remaining hidden. Perhaps the most foolish act in human history was to launch Voyager 1 and 2 space probes in 1977 with maps pointing the way to Earth. At some point in the future it will be compulsory to overtake and retrieve these probes before they can be intercepted and deciphered by a hostile alien life form.

### 3. The Fossil Record

If life on Earth has been influenced by an alien intelligence in the form of directed panspermia, there may be some evidence in the fossil record. The primary mechanisms of purely natural evolution are natural selection, sexual selection, mutation, genetic drift, and gene flow. It is unknown if these mechanisms are sufficient to explain the changes that have occurred in terrestrial life over geologic time because the theory cannot be tested in the laboratory. We draw inferences but empirical corroboration is lacking. Natural evolutionary processes act over long periods of time that are far beyond a human lifespan. Conversely, there can be no doubt that natural mechanisms have influenced the evolution of life on Earth. It is virtually a tautology, for example, that an organism best adapted for survival in its environment will have the greatest likelihood for reproduction and thus be naturally selected. The great question is whether natural evolutionary mechanisms alone have the creative power to account for the dramatic changes we observe in the fossil record.

The first person to systematically study the fossil record of life on Earth was the French anatomist Georges Cuvier (1769-1832). In his four-volume treatise *Recherches sur Les Ossements Fossiles de Quadrupedes* (29), Cuvier established the reality of extinction. He also noted that there was an order and "remarkable succession" in the fossil record (30, p. 224). The youngest fossils most resembled existing life, while the oldest fossils bore the least resemblance to existing forms. Cuvier and the English geologist William Smith (1769-1839) are credited with originating the *Principle of Faunal Succession*, the observation that life in each geologic age was unique, "each geologic formation having a different total aspect of life from that in the formations above it and below it" (31, p. 361).

Smith (32, p. 3) noted that each geologic stratum has "the same extraneous or organized fossils throughout its course." Cuvier was so struck by the discontinuous nature of life on Earth that he concluded "life on Earth has often been disturbed by terrible events" (30, p. 190). It is the Principle of Faunal Succession that allows the construction of a geologic time scale and the temporal correlation of rocks widely separated in both space and material composition. If life had evolved gradually, slowly, and uniformly as predicted by known theoretical mechanisms, it would not be possible to construct a geologic time scale. The entire basis of the geologic time scale is that life in each age is unique and represents a distinct break from preceding and succeeding time periods.

According to all known theoretical mechanisms of evolutionary change, life on Earth should have evolved gradually. Natural selection and other natural mechanisms should have been continually molding and adapting life to changing environmental conditions so that every living thing was a transitional form. Yet this is not the case. The discrepancy was openly acknowledged by Charles Darwin (1809-1882). Darwin's theoretical model predicted that "the number of intermediate varieties, which have formerly existed on the Earth, [must] be truly enormous" (26, p. 280). But Darwin frankly admitted that "geology assuredly does not reveal any such finely graduated organic chain; and this, perhaps is the most obvious and gravest objection which can be urged against my theory" (26, p. 280). Darwin attributed the discrepancy between model and data to the flawed nature of the fossil record. Although the fossil record must certainly be fragmentary in the extreme, with nearly all life forms escaping fossilization, Darwin's rationale has always been nonsense. If every life form was a transitional form, then the few preserved would also be transitional (26, p. 282). But this is not the case.

This is not to characterize Darwin's work as bad science. His theory was simple, unifying, and based at least in part on observation. Darwinian evolution

was the final fulfillment of the promise of naturalism that began with the pre-Socratic philosophers in the 6th century BC. After Darwin, science could explain not just physical phenomena such as the movements of the planets, but life itself. Supernaturalism was no longer necessary.

But data are stubborn things. Little has changed since Cuvier noted the lack of transitional forms in the fossil record more than two hundred years ago (30, p. 226). Two centuries of additional fossil collecting has not produced the finely graduated organic chain predicted by Darwinian evolution. "The extreme rarity of transitional forms in the fossil record persists as the trade secret of paleontology" (33, p. 14). As a rule, the fossil record is not a record of continual change but of stasis and sudden appearance (33, p. 14). And this is precisely why Eldredge and Gould (34) proposed the theory of punctuated equilibrium. In this theory, evolution happens through allopatric speciation in small peripheral populations.

Geographical isolation of the organisms undergoing change is necessary to avoid muting and diluting change through gene flow. "New species can arise only when a small local population becomes isolated at the margin of the geographic range of its parent species" (34, p. 94). The model further specifies that speciation be rapid: "most evolutionary changes in morphology occur in a short period of time relative to the total duration of species" (34, p. 95). If this is indeed the case, then the inescapable corollary is that the process of biological evolution will virtually never be recorded in the fossil record, for the process occurs rapidly in small geographic areas. And this is troubling, because it implies that punctuated equilibrium is a theory that cannot be falsified. The theory of punctuated equilibrium is reminiscent of the deferents and epicycles added to the geocentric Ptolemaic model to preserve its integrity. Like a bandage, complexities were layered upon a model to save its explanatory power at the expense of losing simplicity and elegance.

If there has been alien intervention in life on Earth, the best evidence in the fossil record is the Cambrian Explosion. The Cambrian Explosion refers to "the rapid increase in animal diversity and abundance...between about 540 and 520 million years ago" (35, p. 528). It is "a unique episode in Earth history when essentially all the animal phyla first appear in the fossil record" (36, p. 355). The Cambrian Explosion "marks the advent of virtually all major groups of modern animals...within...a few million years" (37, p. 24). "The single most spectacular phenomenon evident in the fossil record is the abrupt appearance and diversification of many living and extinct phyla near the beginning of Phanerozoic time" (38, p. 279).

The most perceptive comments on the implications of the Cambrian Explosion were made by Stephen Jay Gould (37). Gould described the iconographic depiction of the operation of natural evolutionary mechanisms over geologic time as a cone of increasing diversity, where life becomes increasingly complex and diverse over time (37). As Gould (37, p. 39) noted, the common interpretation of evolutionary trees is to conflate "placement in time....with judgment of worth." Human beings appear at the apex of these trees, as if the entire purpose of the last four billion years of organic evolution was the production of *Homo sapiens*. These anthropomorphic depictions resemble the Medieval Chain of Being (39), with their roots in Aristotle's ladder of nature (21, p. 635, 588b). There is one difference: God was at the apex of the medieval Chain of Being, but the evolutionary trees of the 19th and 20th centuries replaced God with man.

The reality of the fossil record is not a history of increasing diversity. As measured in terms of the number of living phyla, the maximum range of anatomical and biological diversity appeared suddenly, over no more than a few tens of millions of years in the Cambrian. "Later history is a tale of restriction, as

most of these early experiments succumb and life settles down to generating endless variants upon a few surviving models" (37, p. 47).

The challenge of understanding the Cambrian Explosion is its uniqueness. If the appearance of new phyla was due to some set of natural circumstances, either environmental, developmental, or ecological, why is it that these circumstances only occurred once in Earth's history? If natural mechanisms of biological evolution have the creative power to fully explain the history of life on Earth, why is it that these mechanisms operated for a relatively brief period of time about 500 million years ago, and were subsequently muted? There are, of course, theoretical explanations involving environmental or chemical changes, but exactly how these might have interfaced with evolutionary processes is obscure. None of these ideas can be tested in the laboratory.

The Cambrian Explosion suggests the possibility of intervention, modification, and direction of life on Earth by an alien intelligence. This is an entirely speculative hypothesis, but nevertheless it is not unscientific, and it is corroborated to some degree by the evidence. Perhaps life on Earth originally arose through a yet unknown abiotic process, or was seeded here by a natural process of panspermia (40). At a point in time coincident with the beginning of the Cambrian Explosion, a fleet of autonomous robotic probes directed by an advanced artificial intelligence system arrived in our solar system and identified the presence of life on Earth with the possibility of cultivation and enrichment. For some time now, it has been argued that "the best way to explore and contact other races is by automated messenger probe" (41, p. 251). The theory of self-reproducing automata originated with the mathematician John von Neumann (42), thus this type of theoretical robotic device is referred to as a "von Neumann probe." Although once confined to the realm of pure science fiction, recent advances in robotics and

artificial intelligence imply the construction of such devices is an inevitable and imminent extrapolation of existing knowledge and capabilities.

If maintained and repaired, a mechanical device such as a robot has an indefinite lifespan. If time is not a limitation, then traversing the enormous distances involved in interstellar travel is not precluded by natural law and reduces to an engineering problem, albeit a difficult one from a present day perspective. Rockets powered by chemical or nuclear propulsion could conceivably reach velocities sufficient for travel times on the order of 10,000 to 100,000 years. Energy during the trip could be provided by radioisotope thermoelectric generators utilizing long-lived isotopes. Power expenditure could be conserved and managed by making most of the trip in a hibernation mode.

The creation of life is a challenging problem, as an alien intelligence must not only design a few living organisms, but an entire ecological system where living things interact and have degrees of mutual dependence. The premise is as earlier stated: given information and energy, anything permitted by the laws of nature is possible. Both information and energy are readily available. The probe or probes will arrive loaded with the information necessary for them to function. Specific data regarding the Earth and the Solar System will be gathered on site. Neither is energy a limitation. The universe is full of energy. The most obvious energy source readily available is solar radiation, with power being generated through either photovoltaic or thermal mechanisms. The energy flux from the Sun has been near-constant for billions of years. Nuclear power is also feasible. The Earth and other bodies in the Solar System could easily be mined for fissionable materials. Perhaps an alien intelligence will be sufficiently advanced as to have the technological prowess to utilize fusion power. Fusion fuel in the form of hydrogen is abundant in the Solar System.

Redundancy will likely be key. One of the first steps for an autonomous probe after it enters the Solar System will be to make copies of itself. If there are multiple copies, each with the ability to diagnose and make repairs on other units, time is not a limitation. Thus an artificial intelligence does not have to "get it right" the first time. It can design and implement an ecological program, then sit back for a million years and watch. The process can be iterated as many times as needed. Although the preceding may appear to be speculative, it is the process that nature itself uses to propagate life. A seed contains information and an initial store of energy. The seed then grows into a plant, gathers energy from the environment, reproduces and evolves.

In addition to the Cambrian Explosion, the fossil record contains other evidence suggestive of the possibility of alien intervention. Morphological stasis is common (43), suggesting the inadequacy of naturalistic mechanisms unguided by intelligence. The Cambrian Explosion was preceded by the Avalon Explosion, a period from about 575 to 542 million years ago characterized by the sudden appearance of soft-bodied, complex macroscopic life forms (44). Another period of rapid evolution and change in life on Earth was the Great Ordovician Biodiversification Event (GOBE), a period from about 497 to 467 Ma characterized by "an exceptional interval of genus-level diversification" (45, p. 652). The thirty million year span occupied by the GOBE has been called "the greatest increase in marine animal biodiversity ever recorded" (46, p. 220). Possible natural causes of the GOBE include climatic cooling and an increase in atmospheric oxygen (46, 2022). Granted, it could be argued that the existence of multiple periods of rapid biological change in the fossil record implies the adequacy of purely naturalistic mechanisms, as these forces are always at work. Certainly, the evolution of life by directed panspermia and purely naturalistic mechanisms are not mutually exclusive hypotheses. The influence of natural (as

opposed to directed) panspermia through cometary bombardment is another possibility (40).

#### **4. Discussion**

Ball (47) proposed the possibility that alien intelligences exist, and "that they are deliberately avoiding interaction and that they have set aside the area in which we live as a zoo" (p. 349). This theory is known as the Zoo Hypothesis. The original idea is probably misnamed. Even if it contains some element of truth, hypothetical management of life on Earth by an alien intelligence is not analogous to a human zoo. Zookeepers make no pretense of hiding their existence and aggressively manage animal habitats.

If life on Earth is managed by an alien intelligence, a garden is a better analogy than a zoo. Why would an alien species want to intervene or manage life on Earth? Presumably, any alien life arose in a context of an ecological system in the presence of multiple life forms. Even in the most alien of beings, there must therefore be some appreciation or interest in other life forms, an implicit recognition of the value of life and the similarity shared by all life forms. Humans delight not only in keeping pets and zoos, but in the cultivation of gardens. Francis Bacon called gardening "the purest of human pleasures" (48, p. 144). If not a zoo, perhaps the Earth is a garden.

Phylogenetic analysis suggests that retroviruses first appeared during the early Paleozoic (49). Steele et al (50, p. 5) argued that panspermia was the "most plausible valid option for the origin of terrestrial life," and suggested that retroviruses (1) could have been delivered to Earth through extraterrestrial bombardment from bodies such as comets, and (2) these viruses may have played a role in the rapid evolution of life during the Cambrian Explosion. Viruses may

influence evolution through horizontal gene transfer and genomic innovation (51). This idea is not entirely contradictory with the possibility of direct action by an alien intelligence. An intelligence capable of abiogenesis may have fabricated and employed viruses as tools.

So far in this discussion, the most serious and important question, the origin of life, has been sidestepped. We clearly now understand however that even the simplest of living things is complex. Life cannot arise spontaneously by mixing chemicals in "some warm little pond" and passing electric sparks through them, as Darwin speculated in 1871 (52, p. 18). Understanding abiogenesis is a challenge. Nowhere on Earth today can the process be observed happening. No human laboratory is capable of creating life from inorganic materials. "All attempts to demonstrate spontaneous generation in the laboratory have led to failure for over half a century" (12). This acknowledgement is a simple statement of fact. It is not an "argument from ignorance" designed to sneak in or justify some aspect of supernaturalism. Naturalism is essential to science.

If we necessarily rely upon purely naturalistic mechanisms to explain the origin of life, we are constrained by the limited age of the universe. The best current estimate of the age of the universe is 13.57 billion years (53). Surely the problem of abiogenesis would be eased if we had more time to work with. In an 1869 letter to James Croll, Charles Darwin acknowledged the necessity of time. "I am greatly troubled at the short duration of the world according to Sir W. Thomson, for I require for my theoretical views a very long period before the Cambrian" (54, p. 163-164).

Indisputably, there is significant corroborative evidence supporting the Big Bang Theory and the concomitant estimate of a 13.57 billion-year-old cosmos. Yet the standard model is not altogether satisfying. It is tantamount to a miracle, an event lacking a known cause. As Hoyle (55, p. 372) noted "it is against the spirit of

scientific enquiry to regard observable effects as arising from causes unknown to science, and this in principle is what creation-in-the-past implies." The older steady-state model (55) is more intuitively satisfying. Nor are steady-state models completely dead. Narlikar and Wickramasinghe (56) point out that recent astronomical data appear to contradict the standard model in some respects. Dunstan (57) postulated that "measured redshifts" may be due "to gravitation rather than recessional velocity" (p. 555). "The steady-state universe is then in a state of dynamic equilibrium where the entropy of the galaxy distribution is opposed to the gravitational attraction" (57, p. 560). With infinite time at our disposal, what is highly improbable (abiogenesis) during a finite period of time can approach a statistical certainty.

Having criticized several ideas for anthropomorphism, it is apparent that the theory presented herein is also anthropomorphic, in that it presumes an alien intelligence will proceed in a manner whose logic is in accordance with human understanding and motive. The only answer is that some degree of anthropomorphism is inescapable, and human beings cannot help being human. We are unable to fully comprehend how other beings might think, or have the imagination to fully envision and understand alien motivations.

Finally, it should be emphasized that natural mechanisms of biological evolution and directed panspermia are not mutually exclusive. The idea of alien intervention in Earth's biological processes lacks significant corroboration. Conversely, given the vastness of both space and time it could be argued that it's unreasonable to conclude that life exists only on Earth, and has been isolated there for more than four billion years. It is best to always entertain multiple working hypotheses (58). Even if significant corroboration is lacking, speculative conjectures may suggest new avenues of research and investigation and function as intellectual seeds that spur future creativity.

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