IV-B

MAN'S PLACE IN THE UNIVERSE AND THE POSSIBILITY OF EXTRATERRESTRIAL LIFE

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ABSTRACT

The last century has seen a growing recognition that the central theme of the universe is evolution. Driven by a universal process towards a state of maximum entropy, increasingly complex structures have arisen: material, biological, sociological, and at least on Earth have advanced to the point of manifesting the phenomena of intelligence and awareness. It is of interest to ask, "Where does evolution go from here?"

Chance plays an important role in nature, and it may be Mankind's bad luck that our days are numbered. But there is no evidence which compels the conclusion, quite often heard these days, that we will shortly destroy our civilization in one of several possible ways. We are already aware that we have the capability to shake off our dependence on this planet and colonize our solar system: what we yet lack is motivation. Beyond that, we can see the possibility of traveling to the stars, and achieving a new evolutionary level: the galactic society.

If we accept this destiny, it becomes relevant to consider whether we are alone in the galaxy. Are we heirs to a galaxy, or do we have neighbors to share it with? The answer to this will have considerable impact on how we evolve. The search for electromagnetic signals of intelligent origin is now within our means, and should be started seriously. We should be prepared to examine openmindedly, and skeptically, evidence of past or present encounters with extraterrestrial beings.

INTRODUCTION

The idea that the universe shows a pattern of development, that time has meaning beyond the cyclic variation of day and night, summer and winter, is an ancient one. It is found, for example, in the philosophy of the Greeks of Miletos.[1] Until a century ago, however, it competed rather unsuccessfully

with other philosophies. Since then, the explosion of scientific research has given the evolutionary interpretation a solid observational basis. Within this framework we view Mankind as the result of a long process of natural selection. The accelerating change in society today may be considered as a part of this process. Yet, Mankind is reaching the limit of Earth's ability to sustain its progress. The choice seems clear - either we must learn to live within the means of this planet, or we must break its bonds.

In this paper, the origin of the modern view of evolution is briefly traced. Evolution is then considered from a structural and thermodynamic point of view, and the current stage of evolution on Earth identified. Mankind's expansion into the solar system is presented as a meaningful evolutionary step. The possibility of Mankind expanding into the Galaxy is then discussed.

The projections of technology in this paper are conservative in that no unknown or unproven physical principles are invoked; future discoveries may well present possibilities that must, for now, be left in the realm of science fiction.

THE SYNTHESIS OF SCIENTIFIC KNOWLEDGE

Evolution as a theme in natural philosophy appears to date back, in modern times, to the 18th century[1]. Vico in his Scienza Nuova, written in the 1720's, presented a concept of social evolution. In 1755, Kant proposed an evolutionary cosmology in the General History of Nature and Theory of the Heavens. Starting in 1784, Herder synthesized these views in Ideas towards a Philosophy of the History of Man, incorporating them in a progressive development that included stars, planets, minerals, plants, animals, men, and society. A similar but more scientific synthesis was achieved by Buffon in his Natural History, which began to appear in 1749. The works did not have a large impact, because they presented the pattern of evolution without identifying the mechanism by which it is

achieved, and because the idea of an evolving universe was in discord with the philosophical and theological mainstream.

In the following decades, observational evidence for geological change began to increase, and in 1830, Lyell published his first edition of Principles of Geology, which accompanied Darwin onboard H.M.S. Beagle. During this period, Lamarck documented the palaeontological evidence for a progression of organic forms in his Zoological Philosophy (1809), but again the lack of a credible mechanism, and the opposition led by Cuvier in France and, surprisingly, Lyell in England, prevented its acceptance.

The deadlock was broken by the recognition of the mechanism for biological evolution, which appears to have been stimulated by Malthus' "Essay on Population" (1798). Spencer, in his "Theory of Population" (1852), suggested that the struggle for existence leads to a survival of the fittest. The same realization had come to Darwin in 1838, but his Origin of Species did not appear until the independent discovery by Wallace forced its publication in 1859.

Even as the Origin of Species was being published, Spencer was already at work on the amalgamation of science which was to be his life's work. In 1862, First Principles appeared, in which he sketched the great canvas: nebulae evolving to planets, the formation of oceans and land masses, the beginning of life, its evolution to higher organisms, and the development of social structures. He followed his introductory work with many stout volumes progressing in an orderly manner from biology to psychology, to sociology, political philosophy and ethics. Perhaps because of the many weaknesses which are inevitable in such an undertaking, the full force of this synthesis was not immediately appreciated. However, the explosion of research which this century has seen has not resulted in any basic divergence from his original view.[2]

Perhaps the most philosophically troubling aspect of Spencer's work was his bleak view of the future. Even as there is a universal process of integration, so (he said) there is the antithetic process of dissolution. In time, our species will lose its vigour, society will disintegrate, the species will die out, life will decay, the stars will dim, and the universe will return to an inert state. Because of the Second Law of Thermodynamics, it is still the prevailing view among scientists that life must eventually cease as the universe achieves its state of maximum entropy.[3]

THE PHENOMENON OF EVOLUTION

The grand history of the universe is a common theme that runs through so much of our scientific work. The great explosion whose remnant glow is still detectable, the universal expansion, the condensation of galaxies with several stages of star formation, the great clouds of dust and gas which locally condense and finally collapse, the formation of the solar nebula, the condensation of the planets are all key chapters, still the subject of vigorous astronomical research.

The next stage, the leap from astronomy to biology, is the most obscure. The surprise of finding complex organic molecules in interstellar space is over, and there is little doubt that, when its microwave spectrum is determined and enough sensitivity is achieved in our instrumentation, we will find glycine, the simplest of the amino acids, somewhere in space. If such molecules will form in space, we can reasonably assume that Earth's early atmosphere and oceans were also able to synthesize complex organic compounds. How we get from there to the cell is still a mystery. Viruses must represent some kind of clue, but the present variety are parasites only requiring a living cell in which to function. Perhaps the results of Viking are one piece in this puzzle and other insights may be found in the atmospheres of the Jupiter, Titan or Venus.

Beyond the first cell, the evolutionary history is also well known: from single cells to colonies of cells, such as slime molds, next to true organisms, from simple ones such as jellyfish to the immensely complex homo sapiens, a development under the relentless pressures of competition and environmental dangers.

What is the underlying pattern to this process? In Figure 1 are two lists of aggregates. At each level in the table, the component parts are of the same kind. The primordial universe and an atomic nucleus both consist of subnuclear particles. A plasma and a molecule both consist of ions and electrons. A dense interstellar cloud and a molecule of DNA are both composed of simple organic molecules. Cells are the basic building blocks both in bacterial colonies and plants and animals. Individual insects comprise both a swarm of flies and a colony of termites, or bees, or ants. At the left of the table, however, are examples of aggregates with a low degree of organization, whereas on the right the examples exhibit a high degree of organization. Further, the arrow of evolution may be clearly discerned. The highly structured entities on the right at any level of the table become the building blocks for the aggregates on the next level down.

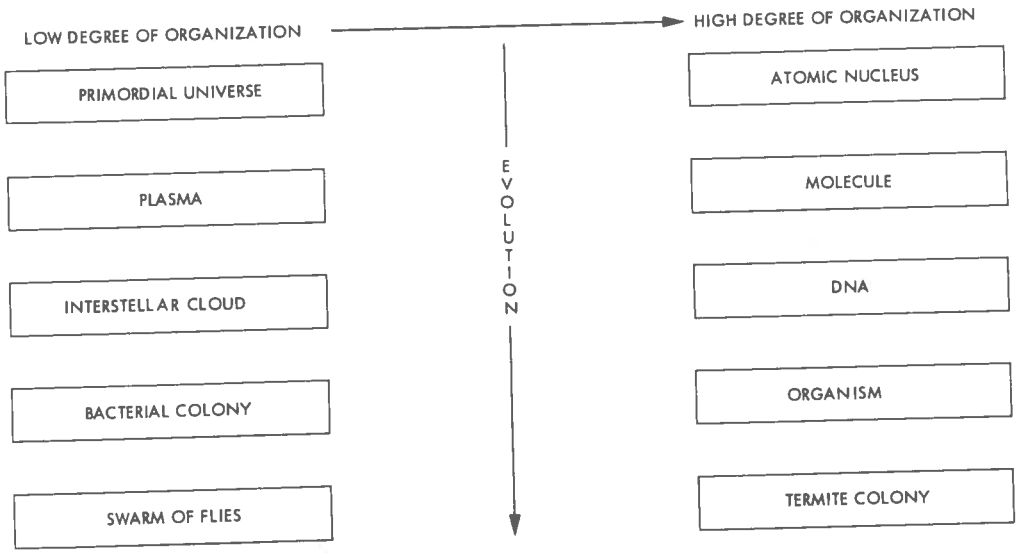

Figure 1. Organization in the Universe

In attempting to locate Mankind, a collection of organisms, in this table we seem to encounter the problem of free will. With our high degree of interdependence, we are quite unlike a swarm of flies or even a school of fish. The extent of specialization among individuals is more suggestive of a colony of termites or bees, although the specialization of function is not strongly reflected in the structure of the individuals. Spencer believed society to be an organism, with organs of nutrition, circulation, ordination and reproduction. On the other hand, our personal experience is that we are not locked into simple deterministic behavior defined by our social function, but have rather a high degree of choice. In 1907, the French philosopher Henri Bergson pointed the way around this problem in L'Evolution Créatrice. By virtue of our memory we retain previous experiences upon which we draw when we must make a choice. Our ability of abstract thought allows us to picture the consequences of each possibility by analogy to previous situations. It is this awareness of ourselves, not only in actuality but in potentiality, that he considers consciousness, and free will is the expression of this consciousness. It should not be surprising that there is often a significant majority in the expression of choice, as individuals rely on similar experiences and education, but this cannot be taken as evidence of a lack of free will.

In this brief sketch we have focused on the structural aspect of evolution, the trend - chemical, biological, social - towards forming more precisely organized structures. There is a complementary thermodynamic viewpoint.[2] In the presence of a continuous supply of free energy, an open non-linear system can be driven far from thermodynamic equilibrium and exhibit coherent behavior.[4] A simple physical example is the establishment of a convection layer in a star: when an atmospheric layer is driven a critical distance from thermodynamic

equilibrium, as characterized by the temperature gradient, part of the energy of the system is transferred from random atomic motions into macroscopic convection patterns. Thus, an open system can achieve a steady state which is characterized by a higher organization (lower entropy) than a system of similar composition in equilibrium. In this view, the evolution of living systems is a progression to successively more organized steady states, characterized by increasingly greater utilization of the available free energy. This interpretation seems consistent with the observation that the higher organisms have higher metabolic rates, and that a highly organized society consumes more energy per capita than a primitive one.

We have sketched a process in which evolution is seen as the integration of disordered components into an ordered state characterized by a greater energy usage and having a higher survival value. Each level of integration provides the raw materials for the next level.[5] At present, evolution on Earth is focused on the integration of Mankind. It is an implicit recognition of the growing unity of Mankind that we are now much concerned with global crises. We recognize that there are serious threats to the entire species - the threat of nuclear self-annihilation, the threat of the exhaustion of irreplaceable resources, the threat of spoilage of renewable resources by pollution. Though not often considered, there is also the more remote threat of global catastrophy of cosmic origin[6], such as a nearby supernova, a collision of the Earth with a wandering planet or asteroid, a major perturbation in solar emission. Indeed, implicit in these threats is not only the essential unity of Mankind, but the essential unity of the Earth. Teilhard de Chardin[7] has suggested that Mankind is now undergoing not only its own integration, but also its "planetisation". That is, we are now undergoing a process of "compressive socialization" which will,

hopefully, lead to a planet in which the interdependency of all parts - sentient, non-sentient, living and non-living - is recognized, respected, and preserved. The Earth will be, in a sense, one organism.

This brings us to a potential crisis which does not yet receive much attention. Von Hoerner[3] has described this as the crisis of stagnation. What does the future hold in store when we have stabilized our population, controlled our rapacious exploitation of mineral and living resources, learned to recycle or de-toxify our wastes? Mankind and its environment, in the absence of external stimuli, may achieve a steady state. Even if, stimulated by our ever-increasing knowledge, we continue to develop within this local environment, our achievements though satisfying to ourselves, will have little or no impact on a cosmic scale. In order to continue to participate in the process of evolution, it will be necessary for us to reach out to similar entities (independently evolved or spawned from us) and seek a higher level of integration.

THE NEXT STEP

Teilhard de Chardin suggested that Mankind and other sentient species will evolve spiritually, towards a universal intelligent entity: a God! Whether sentient life can escape the fate of the material universe (if, indeed, we have correctly perceived this fate) must, for now, be a matter of faith. In any case, such an evolutionary step would seem to be far into the remote future. It will be sufficient for our purpose if we can anticipate the next step.

I think that it is now pretty well established that we are capable of establishing a planet-free society. The work of O'Neill and his collaborators[9] has shown that it is feasible, if still expensive, to establish permanent space colonies and that such colonies could achieve a relatively large degree of independence from Earth resources. From a thermodynamic point of view, this offers a great opportunity for further development: we have the means to go directly to

the energy supply which drives our biosphere, and can have a sink for material and energy wastes which is practically infinite. I am not talking about space as a source of supply and waste disposal for the Earth, although that can be the initial justification for a major extension of our space program.[10] Rather, I'm suggesting that we can now envision a society which is at home in our solar system because, by virtue of the low cost of energy and mineral resources, individuals can achieve a wealth and life style not attainable on Earth.

It is interesting to speculate on the sociological response to such a development. It seems possible that a solar civilization would initially develop quite a variety of social organizations and eventually cultures, and that a process quite like the colonization of America might follow. It is worth noting that this would be a period of relative safety for Mankind as a whole: the threats to civilization on Earth would not seriously affect other independent human habitats in our solar system. Attaining this social state is, in itself, sufficient motivation for colonizing our solar system.[6] While access to the abundant supplies of our solar system can greatly improve the quality of human civilization, will it represent a new evolutionary step? Eventually, as Mankind expands to maximize its utilization of the available resources, another re-integration will need to take place and it would be likely, in view of the vastly different environment, that this new level of integration would be quite different from the one we are being forced to develop here on Earth. By this time, and I think that we all overestimate the time that will be required to reach this state, man will need to look to the stars to avoid the crisis of stagnation.

MANKIND IN THE GALAXY

When we look beyond the solar system, two questions come to mind. Can we travel out among the stars? and, Is anyone else out there?

Until recently, the answer to the first question was generally: no. Unless some fundamentally new physics was discovered, it did not seem possible to build interstellar space ships. However, within the past few years, several writers have pointed out that this is an unnecessarily restricted view.[11,12] Once independent space habitats have evolved, it is only a matter of adding an artificial energy source and propulsion system to embark on a voyage of colonization. The energetics of hydrogen fusion suggests that interstellar voyages of not more than a few generations are feasible. Voyages of exploration, which would imply a return trip do indeed appear impractical, but our recent experience in planetary exploration makes it clear that these would be done by expendable, unmanned spacecraft. While the idea of space colonies traveling between stars seems to belong to the realm of science fiction, I think it is not possible to make a convincing case to rule them out.

If we accept this idea, and then make some conservative assumptions about the speed of travel, and the time for a new colony to mature, we come to the conclusion that the galaxy can be colonized in an astonishingly short time, relative to the age of the galaxy, say something on the order of 10 million years.[11,12]

Concerning the second question, "Is anyone else out there?", we are not aware of any reason why, in principle, the chance of evolving intelligent life should be small, but it is possible to imagine some possibilities. First, there is recent evidence to suggest that planets may not be very abundant.[13] Also, we know little about the circumstances in which life forms, or what the first "living" molecules look like. While the evidence from Mars continues to puzzle us, the results do suggest that life is not so versatile as to evolve to a high level under conditions very much different from those which existed on Earth. According to Frey[14], the formation of oceans, believed to be

crucial in the formation of the first living organisms, may be a relatively rare event. Pappagiannis[12] has discussed the evolution from a reducing to an oxidizing atmosphere as a critical step for higher levels of evolution: it is perhaps the first way in which the biosphere becomes entirely interdependent, but, more critically, it provides the multi-cellular organisms the means to support their higher oxidation rate. There are many other factors which may play a role: an effective cold trap to retain water in the atmosphere, an ozone layer to provide protection against UV radiation, a greenhouse effect to maintain the temperature within a suitable range[15]. It is also possible that the rate of evolution is dependent on essentially accidental instabilities: What was the cause of the catastrophic change in the biosphere 65 million years ago, and what role did it play in the rise of the higher mammals?[16] And if, finally, a civilization does arise, is it possible that the break with orthodoxy achieved in a scientific revolution is also dependent on fortuitous circumstances?[17]

While it may be possible to make a case that we are a relatively unique phenomenon, the prevailing view is that we are not. Among the scientific and technological community, there is a school which advocates the importance of a search for radio signals of intelligent extraterrestrial origin. Von Hoerner, for example, has presented interstellar radio communication as one way of avoiding the crisis of stagnation:[8] future evolution driven by a flux of knowledge, rather than energy. A consideration of the difficulty of establishing interstellar contact by electromagnetic radiation alone shows it to be almost discouragingly difficult[18] unless one assumes that the probability of the evolution of technological life is relatively high, or else that the existing civilizations have access to technology beyond our present understanding. Either they must be able to figure out where we are, so that they can beam

their signals, or they must be able to radiate enormous powers isotropically. The desire to establish contact in the face of these obstacles has perhaps led to estimates of the evolution rate of technological civilizations which are too optimistic.[19]

If we now take such an estimate, or even one very much lower, and combine it with a consideration of galactic colonization, we recognize the possibility that the galaxy is by now extensively inhabited. There is, of course, a popular belief that this is so, and that extraterrestrial beings have, in the past, and are now, regularly visiting the Earth. The evidence for this is not yet convincing. However, it is a reasonable possibility. Papagiannis[12] has pointed out that we have not yet observationally ruled out the possibility that space colonies of extraterrestrial beings exist in the asterioid belt - a natural habitat for a species that has freed itself from its natal planet. Then, there are some who state quite categorically that we have never encountered such beings, and therefore, either such beings are rare[20] or interstellar travel is impossible. There is actually another possibility consistent with an extensively inhabited galaxy, namely, that we are being left alone for one of several possible reasons.

Because the question of extraterrestrial civilizations has such an important bearing on our future evolution, it is entirely appropriate to devote a significant research effort towards its resolution. Unfortunately, a perusal of the existing literature on SETI,[22] on UFO's, and other exotic phenomena such as ESP, yields a disappointing amount of prejudiced argument on both sides of each issue.[23] These are interesting and important issues, and there is a dire need for openminded skeptics, people who are willing to examine these issues impartially. And if there are those who see their role as advocating a particular hypothesis, let it be the hypothesis that is tried and not its adherents.

OUR RESPONSIBILITY TO OURSELVES

Figure 2 is an attempt to summarize this discussion. The dashed lines indicate my own guess as to the most probable path for advanced evolution. I would be distressed to learn that we are reaching the limit of our possibilities but, fortunately, I don't see much evidence for this. The other possibilities all lead to some form of galactic community. Perhaps this community interacts only by electromagnetic communications. This is an important hypothesis that we are now ready to test.[18] In the other cases, the community interacts physically. Does this community now exist, or are we destined to form it? To answer this, we should search for evidence of extraterrestrial civilizations. We should search for evidence in the electromagnetic spectrum, and we should follow up, impartially and diligently, any clues we may have here in our solar system. And finally, if we choose to participate in higher stages of evolution, we must dedicate ourselves to a planned and realistic assault on the next frontier, the solar system.

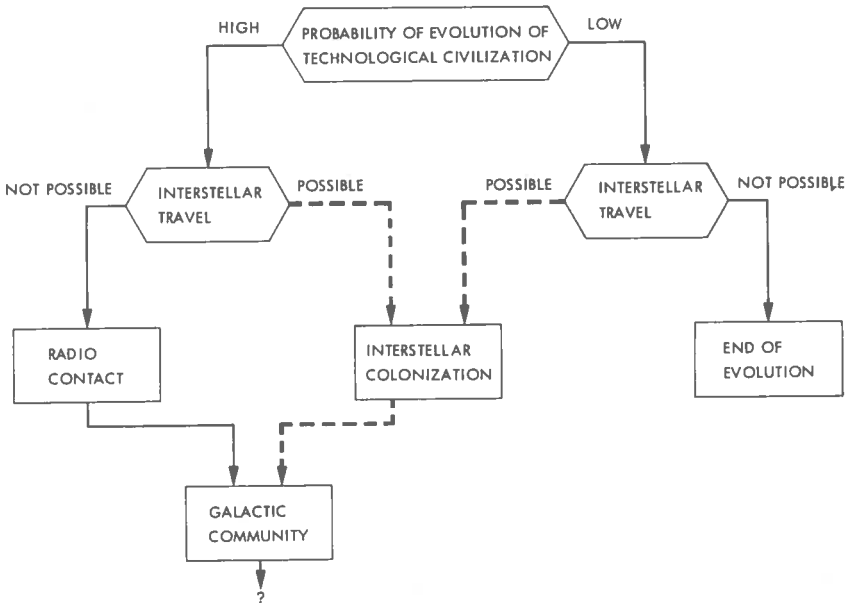

Figure 2

There will be those who feel that a technologically based assault on the universe is crass, self-brutalizing, or wasteful; that we should look within ourselves, explore the realms of parapsychological phenomena, seek a unity with nature on Earth. It is worth observing that, in nature, each evolutionary level represents a greater domination of nature. It defeats and consumes what has gone before. In this light, our concern for the ecology of this planet is not a mystical thing; it is naked self-interest. If we wish to play a higher role in the universe, then we must accept this heritage, and, if we accept it, proceed with the tool we have - our technology. To wait for hypothetically better tools would be like Vikings deciding to stay home until air travel is invented.

Is there a point to it all? Are we only struggling in vain against the inevitable flow of the universe towards its entropic death? I think that to assert this is to place too much reliance on our rather youthful grasp of nature. Teilhard de Chardin's mystical vision seems as probable as Spencer's gloomy view, and may usefully serve to bring religion closer to the scientific world model.

In summary, our present knowledge of the universe indicates a clear pattern of evolution. At present, evolution on Earth is focussed on the integration of Mankind with his environment. If the process of evolution is to continue beyond this level, we must come to interact with similar civilizations. Such civilizations may already exist and even have achieved this integration in the form of a galactic society. We should begin to devote resources to the search for such civilizations. In the event that such civilizations do not exist nearby enough to permit contact, or in order to meet them on a more equal level if they do exist, we should begin the colonization of space.

FOOTNOTES

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24. I am grateful to B. Gary, S. Gulkis, M. Janssen and T. McDonough for critical reviews of this paper.