# WHEN IS EXTRA-TERRESTRIAL LIFE INTERESTING?

*by Solomon W. Golomb*

In order to discuss extra-terrestrial life intelligently, we must first have some working concept in our mind of what is *life*. The point of view that I would like to take is that life is basically a *systems* concept, and that the particular *components* used to realize this concept may be quite different from planet to planet. The systems concept itself involves *growth* and *replication*. Of these two, it is the replication aspect which is most characteristic of life. In other words, we are talking about structures, or machines, or devices, or organisms which are capable of making copies of themselves from the raw materials at hand in their environment, and we will regard such structures as *life*.

There is every reason to assume that many different components could be used to embody this systems concept. In fact, a prevalent view among biologists who think about such matters is that the conditions needed for life to evolve are quite simple. First of all we require *soup*, by which is meant any good random mixture of chemical elements or compounds such as the oceans on earth have ideally provided for the origin and evolution of earth life. Next, we need free energy, such as solar radiant energy, to bring about interactions between the ingredients in the soup, plus sufficient time for something to happen. You may recall Thomas Huxley's analogy that if you let the monkeys type on the keyboard long enough, sooner or later they will type out a meaningful word or sentence, or ultimately perhaps even a volume.

Presumably, the richer the soup and the more abundant the free energy in the environment, the less time will be required for the appearance and the subsequent evolution of living forms. Conversely, where the soup is a very thin broth and the free energy is meager, perhaps a much greater length of time would be required for the emergence of living forms. But the basic view here is that ultimately life forms will emerge wherever these conditions are at all present.

Several decades ago, the late mathematician John von Neumann wrote an article about self-replicating machines. This was a mechanistic approach to the problem of devices which will replicate themselves, and it described a method of building a self-replicating machine or of designing one. The device was basically a control computer which had the instructions for making a complete copy of itself, which it did step by step from the raw materials at hand. If anyone tried to realize this model of von Neumann's today, he probably would have to enrich the environment by having some finely-machined parts lying around in the vicinity of the machine, but the hypothetical machine must at least be able to look around for the parts it needs and build a copy of itself. Finally, the instructions for doing all this are on some kind of punched paper tape which contains all the coded instructions for building a duplicate machine, and of course the final step in the replication of the machine is simply to make a copy of this punched paper tape.

Von Neumann didn't really know it at the time, but this is exactly what nature does on earth with all terrestrial organisms. Every earth organism, from the simplest virus to the most complicated animal and plant, has a punched tape consisting of long molecules of nucleic acid. Directly encoded in these molecules of nucleic acid are the complete instructions for making each of the enzymes and other proteins and substances which the organism will need. Thus, the structural parts are the proteins, which are actually built and assembled from the environmental materials on the basis of these instructions. This is the basic growth and replication mechanism of all earth organisms.

It is a very singular fact that earth life always uses nucleic acid for the genetic coding. In some organisms only ribonucleic acid (RNA) is used, while in most earth organisms deoxyribonucleic acid (DNA) is used as a permanent or long-term storage and ribonucleic acid serves the function of short-term working blueprints, from which the actual structures are built. But there is a fantastic

amount of fundamental similarity in the basic life process of all earth organisms.

If we find life on another planet, we should ask first of all, "Does it use the von Neumann model of replication?" If it does not, it must replicate by some different or more complicated model that would certainly be quite interesting in itself. If it uses too much of a short cut we might even wonder if it is sufficiently elaborate to be life, even in a very general sense of the word. For example, we don't regard crystal growth as biological replication. But certainly the question of what systems concept is used for replication is, from my point of view, the most basic one we can ask. Beyond that we can start looking for similarities with our own forms of life. For example, we would ask if the chemistry of these organisms is based on carbon, or whether, as various science fiction stories have suggested from time to time, a silicon life, or a boron life, or an iron oxide life is involved.

In terms of the *processes* of life we can certainly expect a great deal of variation. For example, we might ask whether it uses oxygen or fluorine or, as in the case of some earth bacteria, sulfur, as the oxydizing agent in its metabolism. Even here on earth we have more than one chemical element used as the oxydizer. When we start looking for really close similarities to earth life, we can ask if it uses the scheme universally prevalent on earth of nucleic acid for the genetic code and protein as the structural substance. Any nucleic acid-protein life would, of course, look extremely earth-like.

### *Structure and adaptation to environment*

There are other interesting questions which in this context are somewhat less basic. These are questions concerning structure, and adaptation to the environment. Does the planet have animals and plants in a recognizable sense? Are there analogies with terrestrial forms as far as adaptation to particular kinds of environment? These will be very interesting from the point of view of classical biology, whereas the kind of questions I have been asking are the ones the microbiologists, or "modern" biologists, would certainly be more interested in. With these ideas as a basis, we can classify extra-terrestrial life forms according to the following scheme. A major category would be *von Neumann life*. As a subcategory of this, we would have *carbon-based von Neumann life*. A subcategory of that would be *nucleic acid-protein life*, and here we could even have the further subcategory of nucleic acid-protein life using the genetic code universally employed by all earth organisms from nucleic acid to protein.

### *Crick-Watson life*

I would propose to call this narrowest category *Crick-Watson life*, in honor of the 1962 Nobel Prize winners in medicine and physiology, who discovered the structure of DNA; and I would tend to believe that any nearby planet on which we find Crick-Watson life has a physical link with earth life. This would certainly be true if the planet in question were Venus or Mars, where we could invoke the "cosmic spore" theory, which asserts that tiny spores, driven by radiation pressure, or Brownian motion, can effect the transference of life from one planet to another close by.

On the other hand, if the code were different—and, a fortiori, if it were not nucleic acid-protein life, even if it were carbon life—I would certainly suspect that the entire evolutionary system on that planet was quite independent of the system on earth. That is, I would postulate a separate Book of Genesis to account for all the life that we would find on such a planet.

A question which has appealed very much to the Sunday supplement publications on the subject of extra-terrestrial life is whether or not it is intelligent. Here too, my approach would be to look at intelligence as a systems concept in the sense of memory and processing, and then the question that I would ask about extra-terrestrial intelligence, whether it were in a simple organism or a complex organism, would be whether the computer organization of this intelligence was similar to what we have found in earth life. For example, does the alien information processing involve something which is *functionally* similar to neurons, rather than something with elements *structurally* similar to neurons.

I feel it is more likely in the near future to learn interesting things by asking this kind of question than by asking, "Well, what do they know that we don't know?" and, "What have they figured out about nuclear weapons and rocketry, or disease control, or immortality, or some of the other technological topics that we have been interested in?" I suspect it will be a frightfully long time, if ever, before we find a life form that is more advanced than ourselves in worrying about precisely those questions that have been of particular interest to the human race. I would be quite surprised, at the very least, to find such life forms in the solar system.

Considerable attention has been given recently to concern over the possibility that space probes launched from the earth and landing on the moon and other planets might cause biological contamination of those planets, and, of course, this is a legitimate cause for scientific worry. However, there is a much more basic problem that we are faced with when we start talking about the interaction of possibly quite alien life systems. At the extreme of high organization and intelligence, we have the problem of facing the aliens who are smarter than we are, and who are similarly given over to aggressive militaristic passions and would therefore destroy us militarily.

I don't lose any sleep over that one at all. It is not the sort of thing that I am worried about as a possibility within our solar system or within my lifetime. It becomes a possibility when we start fooling around with contacting people in different parts of the galaxy. If they're bright enough to be contactable, they might be formidable opponents. The history of our species has been that whenever human beings have encountered a very similar life form with comparable intelligence—other tribes, other races, or other nations—their instinctive reaction is to have a military showdown first, and compare notes on the niceties of civilization afterwards. But, as I have said, this is not my immediate concern.

### *An assortment of dangers*

The science fiction writers have in fact done a fine job of describing intergalactic warfare, and I couldn't hope to add anything to that. H. G. Wells described another menace which is also reasonably obvious; namely, that the diseases of one planet may be far more severe for the inhabitants of other planets who haven't built up an immunity against them. This was certainly the history of the European explorers in the New World, and has been one of the great problems whenever cultures on earth have interacted. The transfer of disease has been quite violent and virulent. This worries me somewhat in its implications for exploration even within the solar system, but I think that rather routine quarantine procedures could be developed which would handle this problem without too much difficulty, as long as the problem is recognized in advance. I am reasonably hopeful that it would be.

The thing that concerns me most is the competition that could go on, and sometimes inevitably would go on, between truly alien systems of life at the *microscopic*, almost at the *molecular* level, when it comes to competing for the basic raw material out of which they make replicas. This would involve competition as to which is the more efficient energy conversion system. The fact that there is only one mechanism on earth for replication is not necessarily the result of only one system having evolved. In fact, our present system is not likely to be the original form in which a replicating mechanism evolved. Apparently there is a "zero-one-law" of survival among replicating mechanisms leading to the survival of one system and the extinction of all others. After the first one has appeared, and it may have taken it millions of years to emerge, then there is suddenly a strong competition among slight variants of this replicating mechanism as to which one can make replicas faster. That is, the one that is most efficient at it is using up all the raw materials from the environment, and the others are starved out.

### *The most efficient replicating mechanism*

What we have on earth is apparently the result of just such a situation as this, where the nucleic acid-protein mechanism turned out to be more efficient than any of its competitors, and took over. It is certainly conceivable that there is a mechanism on Mars or on Venus that is inherently more efficient than the earth mechanism, and if we were to introduce some spores or some microorganisms of that type on earth, it is just possible that gradually, over a period of decades, or generations, or centuries, these microorganisms might take over the ecology of the oceans or of the soil on earth. Then, at the most basic level of the food cycle, they might make the oceans incapable of supporting the usual kinds of fish and other seafood, or they might make the soil incapable of supporting grass or animal life. At such a point, without anybody ever having fired a shot, we would have lost the entire battle of survival.

I prefer to believe that life which is very well adapted to Mars, even if we say that Mars is a more hostile and inhospitable environment than earth, would not as a consequence be all the more hearty and successful when it came down to compete with the soft, coddled life on earth, just as desert plants do notoriously poorly when brought into lush tropical regions. However, the consequences of guessing wrong on this point are unspeakably disastrous, and I think we should pay a great deal of attention to this particular danger.