# SUMMARY OF SESSION III
# UNIVERSAL ASPECTS OF BIOLOGICAL EVOLUTION

John Billingham
Ames Research Center
Moffett Field, CA 94035

The Session was opened by the Co-Chairman Dr. Lynn Margulis of Boston University.

Leslie Orgel gave a paper on Molecular Replications. He described current concepts of the genetic code, built on the message carrying sequences of four bases, adenine(A), thymine(T), guanine(G), and cytosine(C). He noted that the pairing of the Watson-Crick system is of complementary bases, A-T and G-C, and asked the question whether there could be symmetric pairing, C-C. The magic of the system is self-replication. From a single molecule can be produced an exponentially growing number of message carriers. How did the process get started on the newly formed planet? Orgel went on to describe some of his laboratory experiments on strands of poly-C, which will line up with poly-G, and on other base combinations with different metal catalysts, in an attempt to understand the fundamental chemistry of pairing and replication. He warned that we are still woefully ignorant of the real evolutionary sequence of the earliest self-replicating systems, and reminded everyone that there is only one sample of life to study - that here on Earth.

The Precambrian Evolution of Terrestrial Life was the title of the next paper by Andrew Knoll. He gave a vivid picture of what is currently understood about the immensely long period of the early evolution of life. It is not yet clear whether the 3.8 billion year old (byo) rocks from Isua in Greenland did or did not contain life: they are strongly metamorphosed. It is clear that 3.5 byo rocks from South Africa and West Australia have firm evidence of life in the shape of microfossils and carbon isotope ratios indicative of biochemistry. Stromatolites are also found at this early time, revealing the presence of fairly sophisticated microbial life forms that were prokaryotic, anerobic, but probably already capable of photosynthesis. The time of appearance of free oxygen is not clear, but there is evidence that it might have been present in low concentrations in localized regions as long ago as 3.2 by. By 1.4 by ago there is obvious micro-paleontological evidence for the presence of nucleated species. The first animals are seen at 0.65 by and the end of the Precambrian at 0.60 by marks the boundary between non-skeletal and



*M. D. Papagiannis (ed.), The Search for Extraterrestrial Life: Recent Developments, 529–533.*


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skeletal forms and presages the explosive diversity of the Cambrian era itself. Knoll then asked some very fundamental questions. Does life always take 4 by to reach real complexity? He doubted if there was really anything magic about the figure. The appearance of the oxygen atmosphere, requiring greater production than consumption, was perhaps a function of continental stabilization. Maybe it could have happened 0.5 b.y. earlier, or much later, or never, depending on the tectonic recycling picture. Life clearly used a combination of ecosystem and tectonic recycling. Does one need high pressures of oxygen for the emergence of multicelluar life? This might seem to be the case for life as we know it, but there may be complex forms of extraterrestrial life which do not need such high concentrations. Knoll pointed out that it sometimes seems that early life was slow to evolve and remained primitive over several by. The truth is that the ogranisms of the late Precambrian were extremely sophisticated, even though they were still unicellular. A good portion of the biochemistry we have today was already in place at that time.

Stephen Jay Gould gave an interesting talk on Evolutionary Convergence and the Problem of Intelligence. He noted that life began pretty fast. The oldest rocks that are not metamorphosed already have it. Are there prescribed pathways for evolution? He thought not for early life. Somewhere else prokaryotic life could go on forever. Perhaps there are many different types of early life in the universe. What about intelligence? This could be on fewer pathways. In fact as size and complexity increase there may be general laws which limit the number of possible body plans. If you want to become large and still have enough surface area for the required exchange rates of metabolites there are really only two basic possibilities. The first is to become a ribbon or pancake. The second is to evolve internal complexity with involution of the necessary large surface area just as we have today. Both experiments may already have been carried out in the course of evolution. The Ediacaran fauna of the late Precambrian may in fact have been the ribbon and pancake approach, and not precursors to the Cambrian fauna as has been assumed. Perhaps they have been forced artificially into the later fossil taxonomies, and were really a distinct and separate breed which became extinct. Gould made it clear that if you start evolution all over again it will come out differently. But there may arise similiarities in structure and function out of different lineages. This is the phenomenon of evolutionary convergence, which he went on to discuss in terms of terrestrial examples. There is likely in the extraterrestrial realm to be a huge diversity of biologies, but it may be possible for there to be some measure of convergence among them and between them and us. He went on to discuss the notion that intelligence of the human type could never appear anywhere else because of the uniqueness of hominoids. One has to be very careful with such an argument. Exact replicas of Homo sapiens elsewhere are most unlikely. But extraterrestrial beings having a similiar type of intelligence to human beings are possible. In other words the phenomenon of evolutionary convergence also cannot be ruled out in the extraterrestrial realm.

In the discussion which followed Philip Morrison asked whether there was any evidence that there had been convergent evolution of intelligence on Earth. Gould said no, but that it was certainly not excluded.

Misha Landau presented some cautions and concerns of an anthropologist in her paper entitled "Human Evolution, the View from Saturn". There is a tendency to discuss and describe other species (extinct terrestrial or putative extraterrestrial) with an anthropomorphic and motivational bias that may mislead the researcher. Describing an appendage with flexible fingers and an opposing thumb as being a "grasping" hand evolved for "weapons or tool use" may bias our conclusions and obscure the true evolutionary pressures and behavioral characteristics of the creatures possessing that appendage.

The next paper was by John Sepkoski, Jr. He talked about Periodic Mass Extinctions and their Implications for the Evolution of Complex Life. He described the work recently carried out by himself and David Raup on new data sets from the marine fossil record. It is possible that there may be a periodicity in the timing of the major mass extinctions over the last 250 million years, with a cycle time of some 26 million years. He discussed this against the background of the asteroid impact theory of Alvarez. He reviewed this new theory against the classical story of evolutionary biology which involved slow and steady biological change in an environment which also had slow and steady changes of a random nature. He pointed out the immense destruction which had taken place during the larger mass extinctions and noted that biologists were beginning to think that those events were more important from an evolutionary point of view than had previously been thought. If one now postulates some regularity of extinctions, major new questions must be asked in the field of evolutionary biology. What is their cause? What are the long term effects? Reviewing an old argument that the ascent of the mammals was essentially made possible by the Cretaceous-Tertiary mass extinction, Sepkoski said we should perhaps ask some hard questions about the benefits of mass extinctions. While this might seem to be a contradiction in terms, the contradiction could disappear if the benfits comprise the regular opening up of new ecological niches which allow new experiments in speciation and a more rapid evolution of complex and higher organisms. The Cretaceous-Tertiary extinction was not beneficial to the dinosaurs, but may have been so for the evolution of intelligence. Sepkoski asked broad questions about the possibility of optimum rates of mass extinctions. These questions are clearly of critical importance in thinking about the spectrum of rates of advance in complexity of biology anywhere, in relation to catastrophic changes in the planetary environment from whatever cause.

Rich Mullers' paper was a direct and logical follow-on. He discussed Impact and Evolution. Much of his talk was taken up with a summary of the original Alvarez hypothesis of large asteroid impacts as the responsible agents for mass extinctions; with the relationships between the Alvarez hypothesis and the mass extinction periodicity theory of Raup and Sepkoski; with the subsequent claim, from three separate sources, of a 26-30 million periodicity of the terrestrial cratering record; and finally with the theories now being put forward as possible explanations for periodic large body impacts on the Earth. Muller discussed the idea developed by himself and his colleagues at U.C. Berkeley, namely that a small companion star in orbit round our Sun makes its closest approach every 26-30 million years, gravitationally disturbs the Oort Cloud of comets over a two million year period, sends an additional $10^9$ large comets into the solar system, of which some 20 strike the Earth and are responsible for the mass extinctions. Another theory involves the oscillation of the solar system in and out of the galactic plane. Muller described the search going on for the postulated companion star (boldly called Nemesis) and he discussed the importance of these major solar system phenomena for the understanding of the general laws of biological evolution in terms of the influence of catastrophic environmental change.

The remaining three papers discussed very broad theoretical concepts of the universe and life.

Minas Kafatos described his Universal Diagrams. He has attempted to relate basic physical characteristics of all objects in the universe by graphical relationships between the quantities of mass, size, luminous output, surface temperature and entropy. Each graph shows some major trends and includes various forbidden regions. The explosion of all terrestrial H-bombs, safely out in space, would fall in the diagrams at a place so different from the natural signatures of the universe that it might be considered to be an artifact. Perhaps therefore it might be used as an interstellar signal between intelligent civilizations. But one should note that it would be the briefest of signals.

John Ball discussed Universal Aspects of Biological Evolution. He claimed that the laws of biology and biological evolution are essentially based on the laws of physics and chemistry, and that there are ways of characterizing biological systems in physical terms which might be helpful in the understanding of the development and limits of biology on a planet. He reviewed some basic principles of biology and boldly attempted to describe what was meant by progress in biological evolution. He said that it has obviously occurred, that we understand the basic mechanism and that it is predicted to continue on our Earth at this time. His basic hypothesis was that the level of development of biological systems, which has on average increased over 4 billion years on the Earth, can be quantified in terms of information. His hypothesis is clearly worth expanding into much more specific quantities, since classical information theory is inadequate to describe the sophistication of very complex biological systems, let alone their evolution. A new metric should indeed be sought.

Finally Dr. C. Bodifee described his ideas On the Occurrence of Advanced Galactic Forms: a Thermodynamic Approach. He discussed the conditions for the presence of life from the thermodynamic viewpoint. The system must be open so that matter and energy can be fed in and waste and entropy removed. Different types of systems were examined for stabilities and instabilities, equilibrium, and other characteristics. One of his conclusions was that good conditions for life might exist in molecular clouds where there is intense radiation from O and B stars. During the discussion it was pointed out that the O and B stars may not remain for long enough in the cloud for significant evolutionary events to occur, and that their own lifetime is limited.

Some concluding remarks, a condensed version of the above, were made by the other Co-Chairman, John Billingham.

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