Preface

The 1990s was a very exciting period for the planetary sciences because it was then that the first planetary bodies were found orbiting stars other than our Sun. The first discoveries in 1992 involved a pulsar but the orbiting planets were in the range of Earth masses. Unfortunately, these must be dead systems and especially as far as exo-life is concerned. In 1995, however, a body of rather less than Jupiter mass was found to be orbiting the star *51 Pegasus* which is not dissimilar to the Sun. This was exciting because it promised the presence of planetary systems elsewhere in the Universe that were expected to prove similar to our own Solar System. This promise was due for some shocks but more and more systems were discovered and catalogued until today in excess of 300 are known and more are being discovered. These planetary systems might well be expected to support life, perhaps with technological capability.

Bodies of Earth mass cannot yet be detected but technology is being developed that will be able to find them if they are there — and everyone believes they are. If planets like the Earth exist elsewhere around other stars will these bodies also carry living organisms? If so will any be technologically capable? There have been questions in the past whether this might be so and questions why none seem to communicate with the Universe at large. In spite of this negative response it is still interesting to find where such life might be. As a natural part of the Universe such extraterrestrials will be subject to its laws just as we are on Earth. The living Earth then will be an example of what might be found elsewhere so a study of the Earth in its cosmic context will be expected to throw some light on developments elsewhere. This exciting study is what we investigate in this book. We explore the many associated questions and, while we may not offer definitive answers, we will certainly set the questions in a clear universal context. This must involve the cosmos as a whole to gain proper perspective. This all adds up to a most remarkable account of a grandeur beyond our powers of invention.

The ancient Greeks seem to have been the first thinkers who realised the truism that if you want to find out about something then the thing to do is

look at it critically and in detail. This is obvious now although it has been forgotten from time to time in the past. This prescription is as true for the Universe as for a garden flower. Unfortunately the Universe is not as easily studied as is a garden flower. A garden flower can be taken inside the garden shed and dissected: obviously we cannot do this to the Universe! The study of the Universe requires the careful interpretation of the readings from observations using the most sophisticated equipment. Generally speaking there is no experimentation where the object can be manipulated in various ways but only the passive observation of events of the greatest grandeur. Equipment and techniques of sufficient power to begin this endeavour have only begun to be available over the last century and new developments are becoming available all the time. Nevertheless our understanding of the Universe is now reaching quite an advanced stage where many important questions can be given answers that are at least safe for the future. Where has this process got to now? This little book is concerned with one aspect of this wide study — the rôle of evolution in the Universe and the exploration to find if extraterrestrial life might be expected to exist elsewhere. Are we likely to be able to make contact with them if they are there?

Observing the Universe has taught us two important things. First, the present phase of the Universe that we now enjoy had a clear origin some 13.7 billion years ago (Bya). We have not got any knowledge of what existed before that nor why the Universe came into existence nor how it happened. The laws of physics that we understand began then. We can presume that something was "there" to start it all off but what we cannot say from our instrumentation. Secondly, the Universe was constructed not to be a simple static thing with its form given once for all at its birth but rather an entity to change and to evolve. There is clear evidence for this in both animate and inanimate forms of matter. The behaviour of inanimate matter is constrained by what we have discovered as physical laws applied without favour but involving a certain degree of chance. The animate matter also evolves in such a way as to be sympathetic to the inanimate environment that it finds at the time. This process has been described by Charles Darwin in his Principle of Natural Selection by Survival of the Fittest. The evolution of the Universe over time is revealed by observing the incoming radiation of the electromagnet spectrum. The visible Universe has been investigated by using ever more powerful optical telescopes but more recently this has been augmented by infrared and ultraviolet light and by radio waves. Earth based telescopes are now augmented by automatic space probes in orbit about the Earth. When we look at the cosmos we are viewing it in the past and the evolutionary pattern becomes clear as we penetrate further and further into space.

The animate past can also be inferred through the study of fossils and more recently using DNA sequencing. The relevance of fossils has sometimes been questioned in the past but they have now become established as an important and reliable tool in the study of the deep and recent past. One surprising result has been that mankind, Homo sapiens, has also arisen as part of the evolutionary process which is still going on. Such a complex evolution in an evolving Universe must surely imply that extraterrestrials, should they exist, will also have arisen in the same evolutionary way as an integral part of an evolving Universe. We explore these aspects of the Universe in the following six chapters and five appendices. Each is designed to be broadly self-contained and, even though this must lead to some repetition of material, it is hoped the reader will tolerate this to avoid the nuisance of having to go searching in other chapters for things that are needed to allow the argument to flow in the chapter being read. Chapter 1 sets down the observations of the planets of the Solar System and the exo-planets that have been found orbiting other stars like the Sun. The changing physical characteristics of the Earth are set down in Chapter 2. The beginnings of like on Earth and the evolution of microscopic creatures is the subject of Chapter 3 while the wider evolution of macroscopic creatures is he subject of Chapter 4. It has now been established that human mankind has evolved according to the principles of evolution and the evidence for this found so far is treated in Chapter 5. This account does not claim to be comprehensive but is meant to offer a very broad indication of the way evolution has acted on Earth over the 4.65 billion years (By) of its history. This is our only model of the working of evolution with animate matter and is meant to suggest how life may evolve on Earth-like planets elsewhere, should they exist. Finally, in Chapter 6 these arguments are drawn together to attempt an assessment of the possibilities for the existence of extraterrestrial life.

The appendices offer ancillary material designed to give perspective to the arguments in the Chapters. Appendix 1 views the broad Universe while Appendix 2 considers some individual members. The ultimate building blocks of everything in the Universe, animate and inanimate alike, are atoms and molecules. Appendix 3 is concerned with the discovery of these entities which we cannot see with our naked eyes. The production of energy is a vital aspect of a living Universe and will be central to the development of technologically capable extraterrestrial life, as is true fro us, and the various aspects of energy production are considered in Appendix 4. Finally, in Appendix 5, we consider very briefly the development of mathematics as the language of science and technology. This controls our advances in an

understanding of the Universe and the same must also be true of extraterrestrials, should they exist.

This is an elementary introduction to astrobiology and is of the nature of a workbook. The aim has been to include all the many aspects of life in the Universe. It is expected that the reader will wish to extend the arguments to form a personal account of these matters and to this end a Compendium has been added which includes a range of explanations of the various topics involved in the Chapters and Appendices.

The illustrations throughout the book have been assembled from a collection gathered over the years some of whose origins I do not now know. I hope those sources not mentioned will be understanding and not interpret any lapse on my part as discourtesy. It is a pleasure to thank Dr. N. B. Brindle, Reader in Cell Biology at the University of Leicester, for his very helpful comments on certain of the biological aspects of the book. I must also thank Mr D. G. J. Cole, M. Sc., for enlightening comments on various matters but especially concerning Gödel's Incompleteness Theorem. Any errors remaining are, alas, my own. I hope the reader will find the book pleasing to read apart from being interesting and useful as a basis for further studies. Its success will certainly owe much to the professionalism of the members of the Imperial College Press and especially to Kim Tan and her colleagues. Apart from affording me their much appreciated support they have made a most excellent transformation from a raw manuscript to a handsomely finished book.

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