MARSBUGS:

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EDITORS' INTRODUCTION
By Julian Hiscox and David Thomas

The summer of 1995 will herald a big step in the field of planetary engineering. The first scientific textbook on the subject of intentionally altering planetary environments, or planetary engineering, will be published. The book is written by Martyn Fogg, an internationally known scientist who has published widely on this topic. Martyn is thus well placed to write such a book. He has also been responsible for editing several special issues of Journal of the British Interplanetary Society on planetary engineering, including another forthcoming issue due out in October 1995.

We are fortunate in being allowed a sneak preview of the book. First, we present the introduction to the book contributed and written by Bob Haynes, an extremely well known scientist not only in his own field of yeast genetics, but also in the field of planetary engineering. Bob was the first person to coin and derive the term ecopoiesis, the end point of which, when applied to the Mars, is the intentional alteration of a presumably abiotic environment into an anaerobic biosphere. Second, Martyn has provided us with a content description of each chapter. Third, because this material is under copyright, and reproduced in Marsbugs with permission of the publisher, we have included at the request of the publisher, publication details of the book and ordering information.

FOREWORD TO *TERRAFORMING: ENGINEERING PLANETARY ENVIRONMENTS*.
By Robert Haynes.

"What I cannot create I do not understand."
Richard P. Feynman, written on his office blackboard as he left it for the last time in January, 1988.

Welcome to the practicalities of orchestrated planetary change. In this fascinating work of scientific synthesis, Martyn Fogg describes how it might become possible to implant life on other planets, and to ameliorate, through ecological engineering techniques, the currently corrosive processes of global change on Earth.

Two important technical terms occur throughout this book: ecopoiesis and terraforming. The first refers to the establishment of evolving microbial ecosystems in initially barren environments; the second to the transformation of a hostile planetary surface and atmosphere into an aerobic environment in which humans might live and work outdoors much as they do on Earth. No one knows whether ecopoiesis and terraforming are scientifically possible or technologically achievable on Mars or any other lifeless planet in the solar system. A research program to assess their feasibility, at least on Mars, would provide a challenging, yet peaceful, objective for human activities in space during the next century. Much of the knowledge gained, especially on the interrelations between planets and life, would be relevant to environmental problems on Earth. For example, there is intense debate over the long-term consequences of large-scale environmental perturbations such as global warming, atmospheric ozone depletion and nuclear winter. These debates arise in the scientific community because we have very limited knowledge of how Earth's global ecosystem was formed, and how its further evolution has been maintained through interactions with the atmosphere, oceans and the planetary crust.

In the spirit of Feynman's remark quoted above, I have argued elsewhere that we may never adequately understand Earth's biosphere until we have learned, at least theoretically, how it might be possible to build another one. A feasibility study of ecopoiesis and terraforming would entail not only further exploration of Mars and other planets, but also studies of the comparative climatic history of Earth, Mars and Venus, the nature of Earth's earliest biosphere, analysis of the origin and operation of Earth's biogeochemical cycles, study of the factors which promote stability in ecosystems, and research on the mechanisms of biochemical adaptation used by organisms living in harsh environments. It is ironic to think that humans ultimately might learn how to preserve life on Earth by studying how to start life on Mars.

Until rather recently, terraforming was more often mentioned in science fiction stories and the popular media than in the technical literature. Fogg's book is the first major study, within the constraints of available knowledge, of the science and technology of ecopoiesis and terraforming. It is a nascent classic, a textbook for the future. Even though the subject matter ranges widely over the physical and biological sciences, the ideas are clearly and logically presented at a level that should be accessible to readers with a basic knowledge of science and mathematics. This is a new field in which there can be, as yet, no elderly experts to gainsay enthusiastic youth. Those with restless yet controlled imaginations, who would escape the confines of narrowly specialized fields, and who would stretch their minds over new, wide-ranging questions, will surely enjoy this book.

The author is a leader of an informal group of scientists, engineers, philosophers and writers who are studying the manifold aspects of ecopoiesis and terraforming. He shows in this book how simple order-of-magnitude calculations (and some computer modeling) may be used to assess the plausibility of the various planetary engineering scenarios that have been suggested.

People can live in inhospitable places in two distinct ways: by changing the local environment, or by carrying a suitable “environment” with them. Desert irrigation for agricultural development is an example of the first, while the life-support systems of lunar landing modules or orbiting space stations exemplify the second mode of survival. The latter devices cannot be inhabited indefinitely; for lengthy stays the crews sooner or later become dependent on resupply missions from Earth. The first human outposts in space will, of necessity, be of the second kind, even though some local resources may be exploited by their occupants. Human settlements on other planets may become fully and permanently independent only if these distant environments are transformed to provide Earth-like living conditions and a local agriculture.

Life is a planetary phenomenon, though Earth is the only presently habitable planet in the solar system. Plants and animals are mutually dependent products of a global ecosystem - the biosphere. All are intricately coupled with each other, and with land, oceans and air by the recycling of water, carbon, oxygen, nitrogen and other inorganic materials required to maintain life. People also are part and product of this complex biogeochemical life-support system, exotic produce of a planetary engine originally set in motion, and continuously fueled, by energy from the sun.

On other planets in the solar system, high and low extremes of atmospheric temperatures and pressures, lack of free oxygen and liquid water, high concentrations of toxic gases, and deadly radiation levels variously preclude the existence of life. Closest to Earth in its astrophysical characteristics is Mars which, whilst presently devoid of life, may possibly possess the chemical resources appropriate for its development.

Despite Mars' toxic environment and the fact that no life exists there now, many geological features of its surface indicate that this world may have once possessed a great northern ocean and substantial quantities of flowing water, together with a thick, mostly carbon dioxide, atmosphere. These conditions might have persisted long enough for early stages of chemical and cellular evolution to have occurred. It is largely for these reasons that some scientists plan to search for chemical and fossil evidence of extinct life during future missions to Mars, and why they have begun to consider whether the planet might ultimately be returned, by human intervention, to a habitable state.

If the surface crust and polar caps of Mars still possess sufficient and accessible quantities of these essential substances, and if acceptable planetary engineering techniques can be devised to initiate planetary warming and secure their release, then Mars could support a stable and much thicker carbon dioxide atmosphere than it does at present. The atmosphere would be warm and moist, and water would flow again in its dry river beds. The average temperature at the surface would rise to about 15 degrees Celsius and the atmospheric pressure would be roughly twice that on Earth. Appropriately selected, or genetically engineered, anaerobic microorganisms, and eventually some plants, could grow under these conditions.

For many people, including some knowledgeable scientists, such an enterprise sounds more like science fiction than any justifiable program for the national space agencies of the world. The technical difficulties posed by the Martian environment, quite apart from the costs entailed, seem almost insurmountable. In addition, the prospect of implanting life on Mars, as a long- range objective for human activities in space, raises many ethical, political and legal questions. Put most simply, do humans have any right to “play God” on another planet?

On the other hand, migration and the colonization of initially inhospitable environments has been one of the most astonishing historical features of biological evolution. The first living cells were formed about 3.8 billion years ago, presumably in the darker reaches of the primeval, anaerobic seas. At that time, much of Earth's environment, and certainly its land areas, would have been hostile, even lethal, to most of the organisms which flourish here today. However, in an amazing biotic Diaspora, microorganisms, followed by plants and animals, migrated from marine to fresh water environments and then onto barren land. None of this would have been possible were it not for the evolutionary development, by living cells, of the “technology” of photosynthesis. Essentially all of the free oxygen (and the resulting ozone shield) in Earth's atmosphere was, and is, generated by photosynthesis. Even though oxygen is poisonous to most anaerobic organisms, its accumulation in the atmosphere, about 2.5 billion years ago, created the conditions necessary for the ultimate flowering of aerobic life as we know it today. The slow chancy processes of genetic variation, natural selection and species diversification made possible the dispersal of non-human life across the globe.

In contrast, the migration and dispersal of Homo sapiens has not entailed any significant biological evolution, and certainly no speciation, ever since the emergence of “modern” humans with linguistic and tool-making capabilities about 100,000 years ago. Rather, it has been the amazingly rapid and efficient processes of social and technological evolution which have facilitated the propagation of our species, across every continent, and most recently into space.

In 1969, astronauts first set foot on the moon. If all goes well, others may arrive on Mars early in the next century. Against this background is it just an idle dream to imagine that people might yet "slip the surly bonds of Earth" to pioneer new habitats in the sky? Further exploration of Mars may well reveal that ecopoiesis, and even terraforming, are feasible on that planet. Such a discovery would provide our decendents with a tremendous challenge and an exhilarating vision of the role of humankind as a catalyst in the creation of new worlds. The propagation of life from Earth to other planets may well prove to be the ultimate legacy of our species in the universe.

Those inclined to deny the possibility of implanting life on Mars should recall that future discoveries often confound the negative prophecies of even the most accomplished scientists. For example, a few years before Enrico Fermi built the world's first nuclear reactor, Lord Rutherford the founding farther of nuclear physics, stated publicly that anyone who “looked for a source of power in the transformation of atoms was talking moonshine.” And at the 1963 International Congress of Genetics, J.B.S. Haldane, one of the greatest geneticists of this century, declared that the deliberate genetic modification of humans must surely lie millennia in the future.

It is rash to proclaim that any process or project that does not obviously violate the laws of physics is impossible. Pliny the Elder (AD 23-79) wisely remarked, "How many things, too, are looked upon as quite impossible until they have been actually effected." We simply do not yet know enough about the geological history and chemical resources of the terrestrial planets, or the origin, evolution and behavior of Earth's biosphere, to do any more than to reserve judgment on the ultimate feasibility of the challenging ideas presented in this book.

Biographical Statement

Dr. Robert H. Haynes is Distinguished Research Professor of Biology at York University in Toronto, and President-elect of the Royal Society of Canada. He is a biophysicist by training and is well known internationally for his pioneering research on DNA repair and mutagenesis. In 1988 he served as President of the 16th International Congress of Genetics.

CHAPTER SUMMARY OF *TERRAFORMING: ENGINEERING PLANETARY ENVIRONMENTS*.

By Martyn Fogg

1. INTRODUCTION.

The history of terraforming-related ideas, in both fiction and academia. A portrait of a growing subject for serious study.

2. CONTAINED, UNCONTAINED AND TERRAFORMED BIOSPHERES.

A review of life-support system dynamics dealing with the issues of scale and containment. An argument for planets as the best long-term homes for life.

3. SOME GUIDELINES FOR THE STUDY OF TERRAFORMING.

The nature of the thought experiment; nomenclature; philosophical approaches to the subject (ecocentrism and technocentrism); environmental parameters necessary for life.

4. PLANETARY ENGINEERING ON THE EARTH.

A review of man's influence on the global environment and proposals for geoengineering - deliberate modification of the Earth's climate, unusually for the purposes of mitigation of damage.

5. THE ECOPOIESIS OF MARS.

Our current knowledge and models of Mars and ecocentric proposals for implanting life. Includes the runaway CO2 greenhouse model; artificial trace greenhouse gases; and proposals for a pioneering microbiota.

6. THE TERRAFORMING OF MARS.

The completion of the Mars thought experiment, taking the planet to the stage of human habitability. Review of technocentric planetary engineering proposals, including nuclear mining, solettas, and impacts.

7. THE TERRAFORMING OF VENUS.

Account of the various and diverse concepts for making Venus more habitable. Includes three proposals for altering planetary spin rates.

8. TERRAFORMING: ALTERNATIVE METHODS, FRINGE CONCEPTS AND ULTIMATE POSSIBILITIES.

Includes paraterraforming; possibilities of terraforming smaller bodies such as the Moon and Titan; proposals for altering planetary orbits and more.

9. BACK TO THE PRESENT.

Discussion of the present relevance of terraforming studies, including pieces on education and environmental ethics. An attempt to speculate from now, to a future that includes the realization of terraforming.

Biographical Statement

Martyn Fogg has an unusual--and somewhat eclectic--academic history. He qualified as a dental surgeon in 1982 from Guy's Hospital Dental School, University of London. Following this, he changed tack to take a mixed degree in Geology and Astronomy from the Centre for Extra-Mural Studies, Birkbeck College, University of London and the Open University, Milton Keynes.

Presently part of Fogg's life is spent as an independent researcher and free-lance science writer. He has a wide range of interests, having published papers on planetary formation and evolution; cometary impact cycles and mass extinctions; blue straggler stars; unbound planets; SETI; the colonization of Mars and terraforming. He has been contributing editor of four special issues of the *Journal of the British Interplanetary Society* devoted to terraforming (a fifth is in press) and has acted as a consultant on the subject to the BBC, TIME/LIFE books and the Japanese Yazawa Science Office. His forthcoming book, Terraforming: Engineering Planetary Environments, is the first technical level book to review modern progress in this field.

PUBLICATION DETAILS

Terraforming: Engineering Planetary Environments will be available in July, 1995. Priced at $49.00, the book can be ordered by contacting SAE, Customer Sales and Satisfaction Department, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

Telephone: 412-776-4970
Facsimile: 412-776-0790

End *Marsbugs* Vol. 2, No. 8.